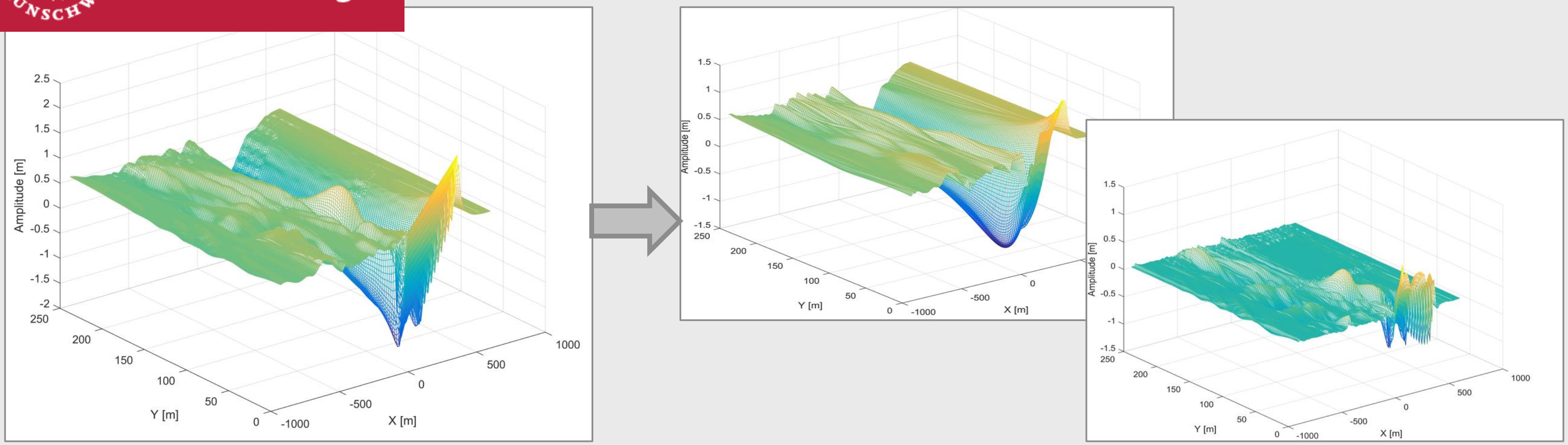
Technische Universität Braunschweig

Leichtweiß-Institute for Hydraulic Engineering and Water Resources
Division of Hydromechanics and Coastal Engineering



Time-frequency analysis of 3D ship-wave fields in maritime waterways

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ICCE 2018

Introduction – Damages as protective structures

Temporal evolution of water level changes and overflow in groin fields due to passing ships

→ **Need for reliable design standards for loads due to ship-induced waves in narrow maritime waterways**

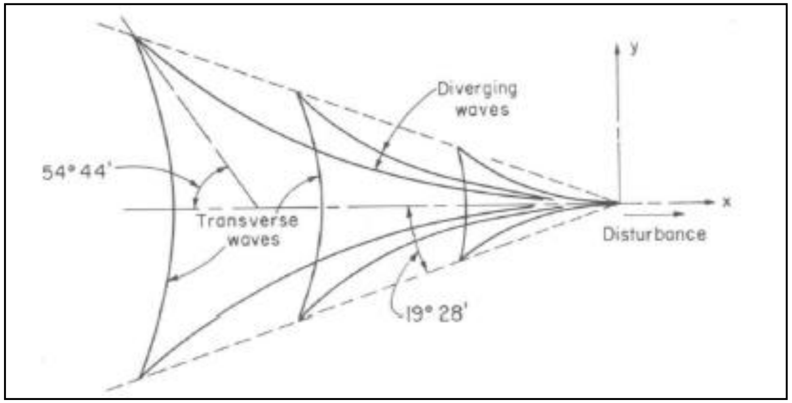
Source: BAW (2012)

Source: BAW (2012)

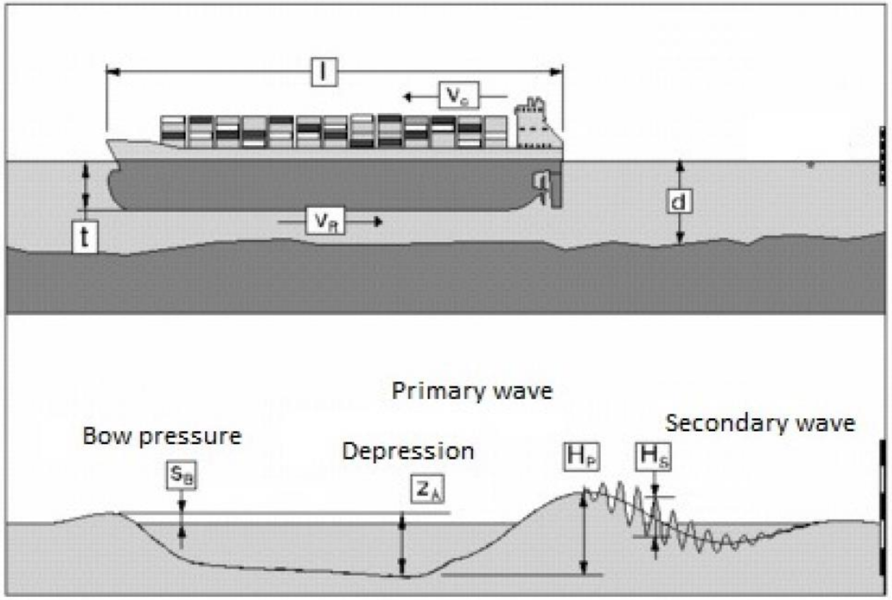
Evolution of damage at groins due to quasi-static overflow of long-period ship waves

Introduction – spatial evolution of ship waves

Crest pattern of a point error moving over deep water



Source: Sörensen (1973)



Source: Sörensen (1973)

Characteristics of ship waves:

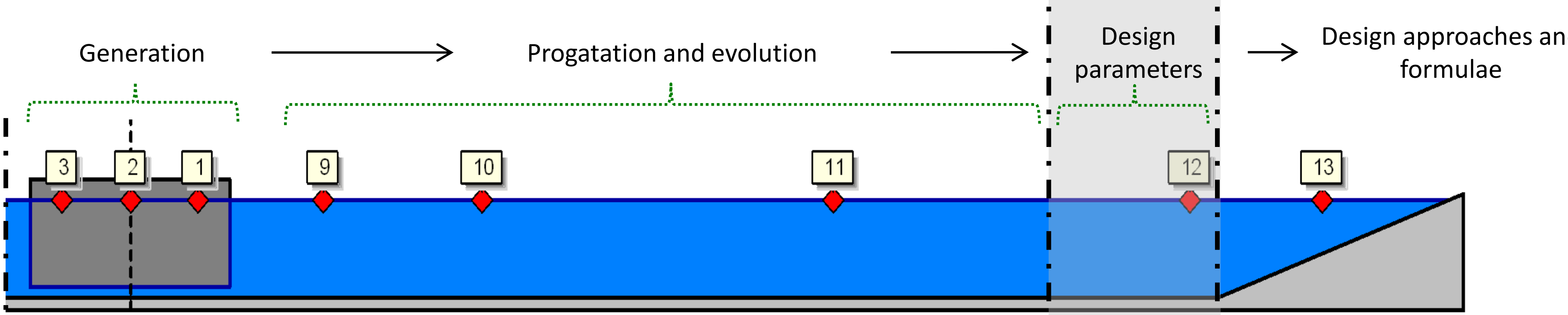
- long-period primary waves, bound wave, travelling along the ship with its velocity and directions
- short-period secondary waves, free waves, propagating under specific angle with their own speed

→ Need for 3D analysis method separating primary and secondary wave

Aim of the research project PaNSiWa

Parameterisation of ship waves

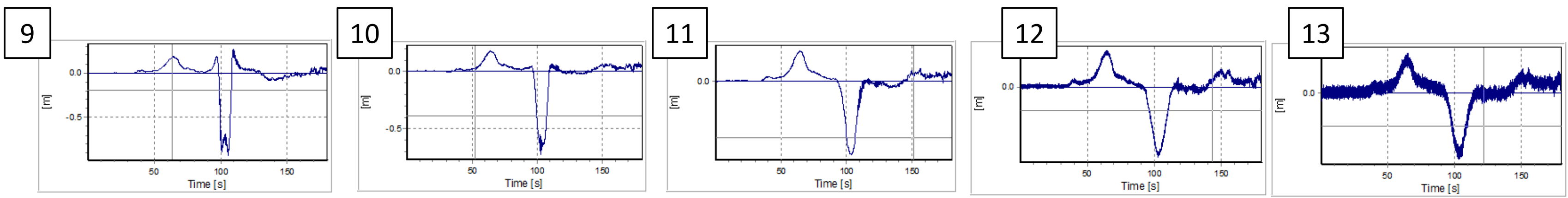
Later: process analysis



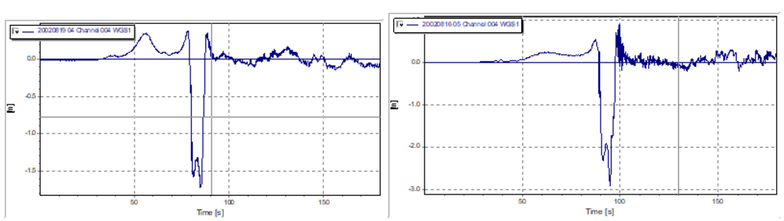
- Distance from ship

Interface between ship waves and bank stucture

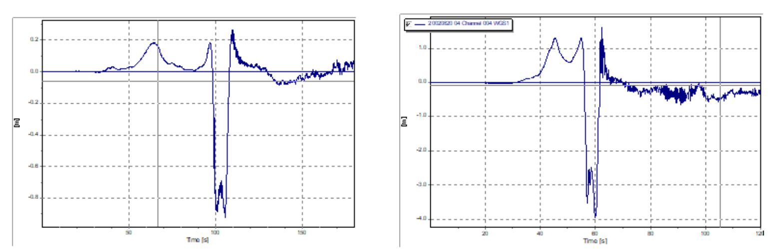
Propagation and evoultion in dependence of



- Typ of ship



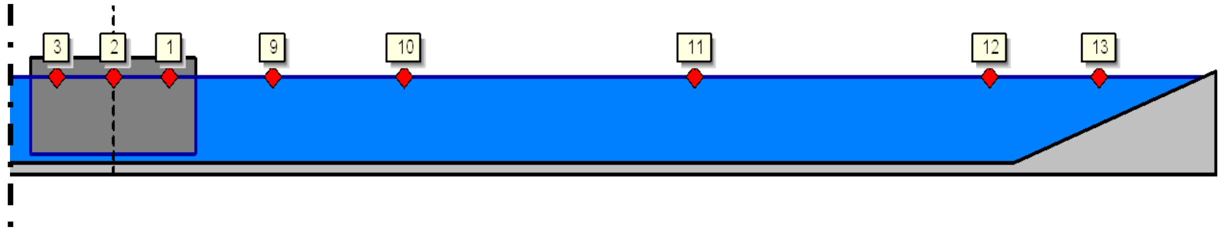
- Velocity of ship



Free-surface ship-wave data for data analysis

Wave gauge data from experimental tests available, but not 3D surface data

→ Numerical simulations (OpenFOAM)



Ship: 360m long, 55m wide, draught 16m

Channel: surface width 536m, bottom width 428m, slope 1:3, length 3860m

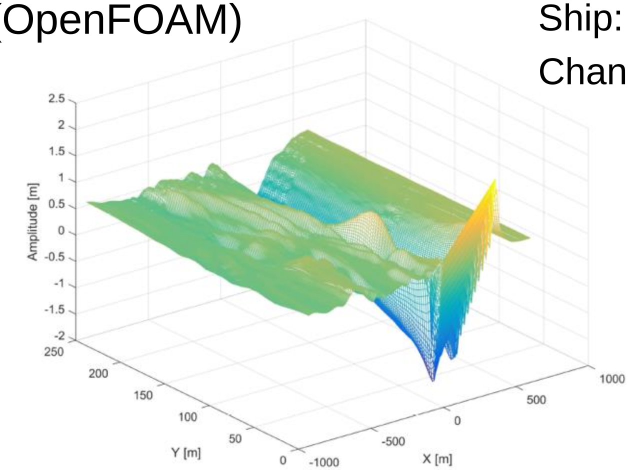
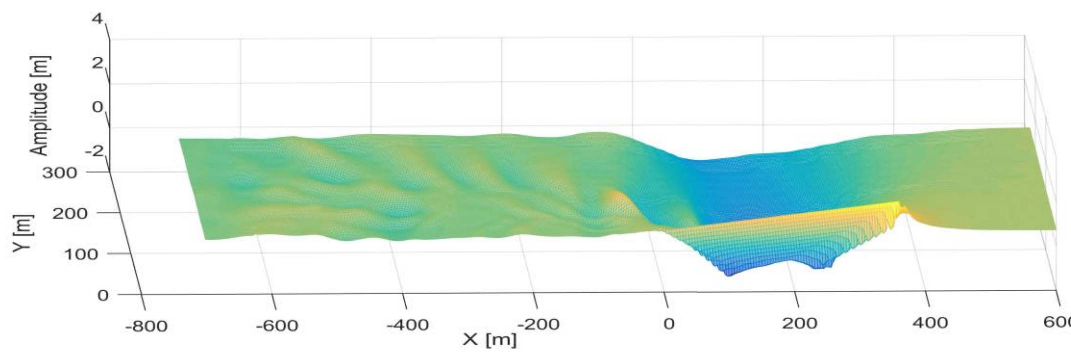
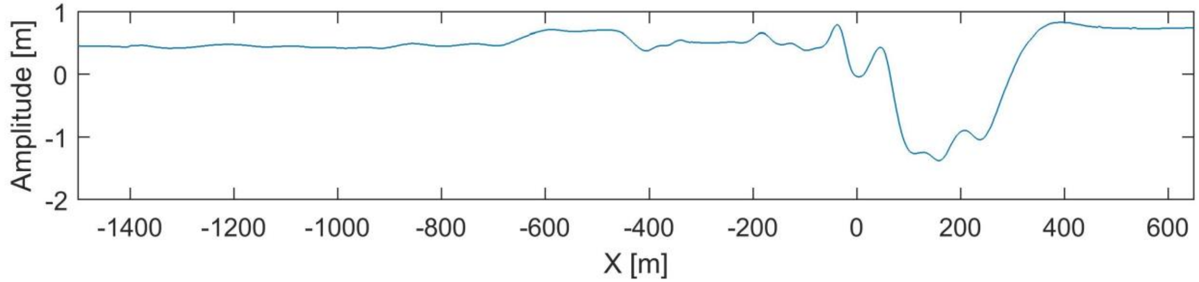


Figure 3.3: Free surface data at $t = 41$ min [9]



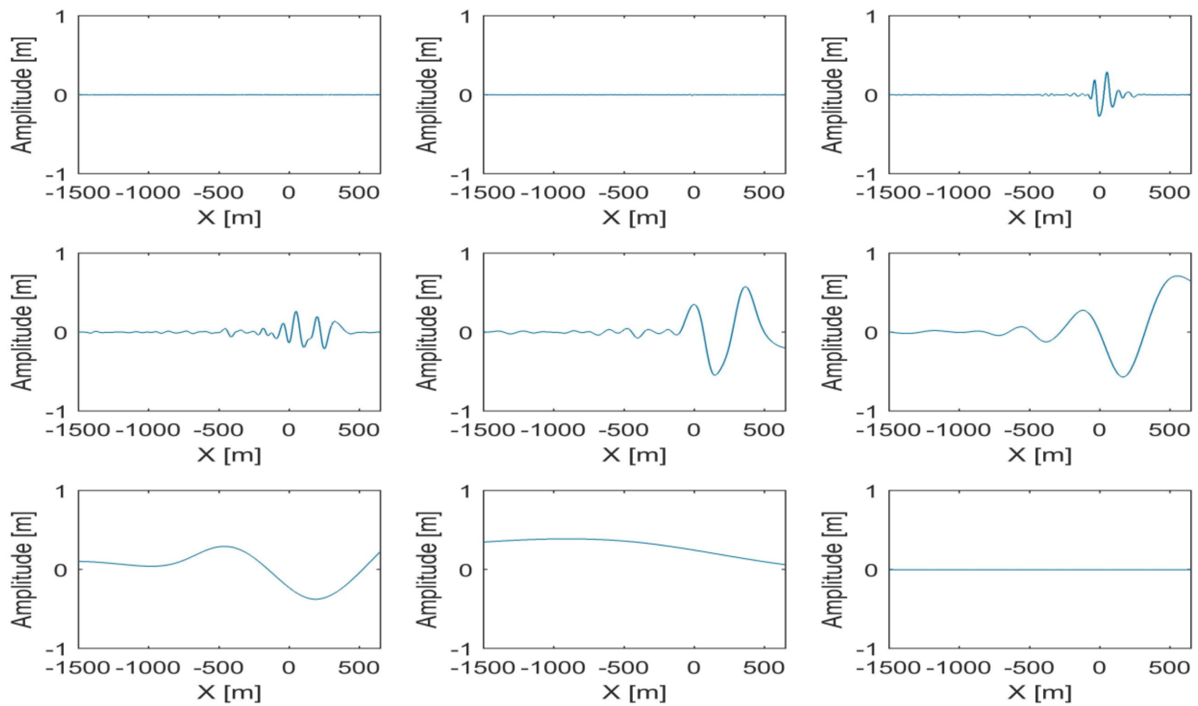
2D ship-wave analysis using HHT

Free surface selected for 2D HHT analysis



2D ship wave at y=51.8 m and t=41 min

Results of application of EEMD, IMF c1 to c9, sorted by frequency



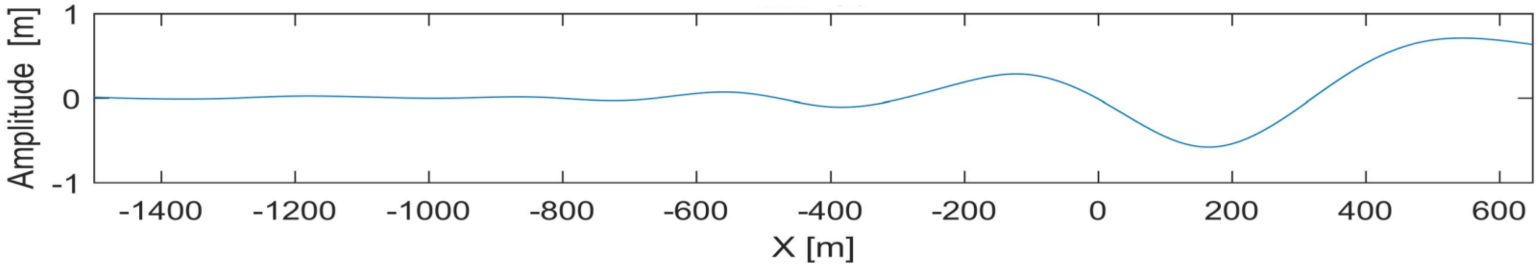
Intrinsic mode functions c1-c9 of 2D ship wave

Huang et al., 1998: EMD and HHT

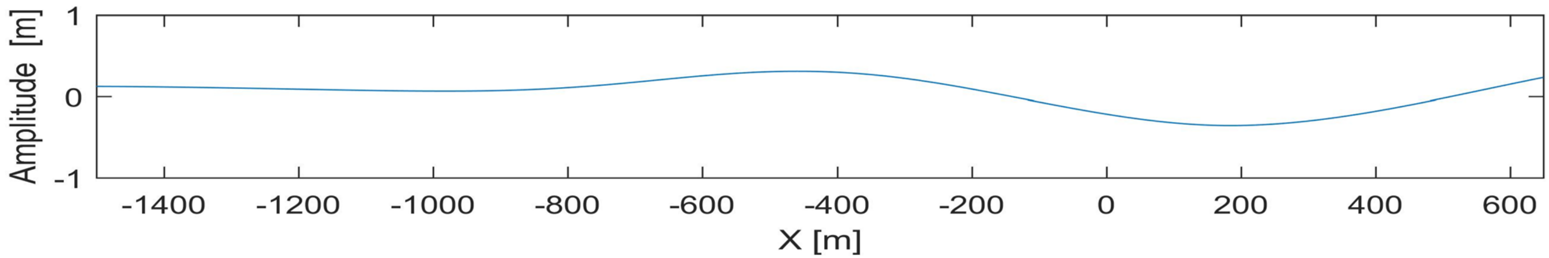
Huang et al., 1999: EMD and HHT

Wu and Huang, 2005: EEMD

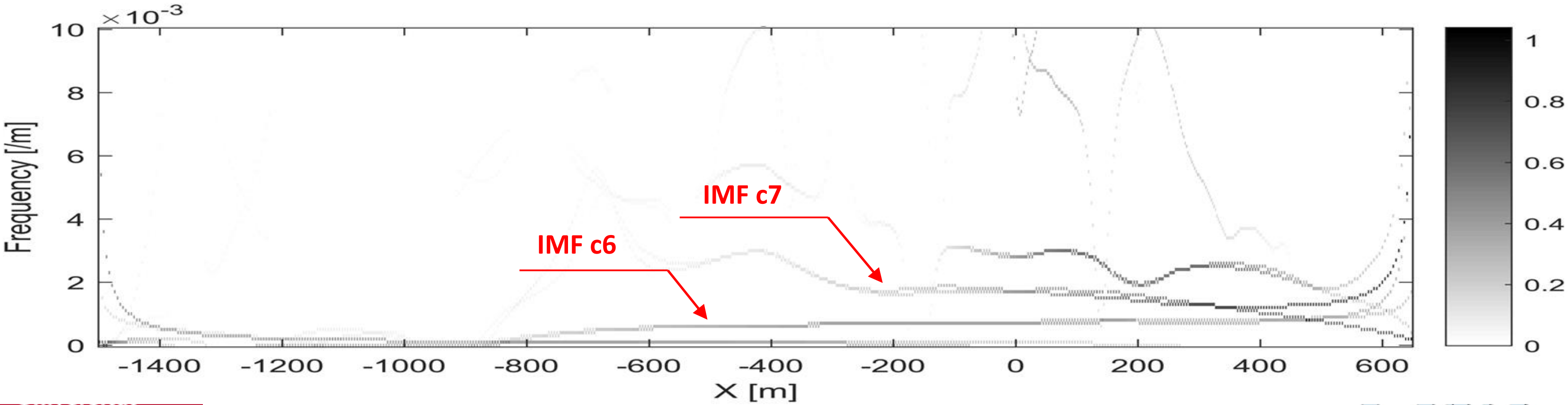
Long-period components in 2D HHT



IMF c6



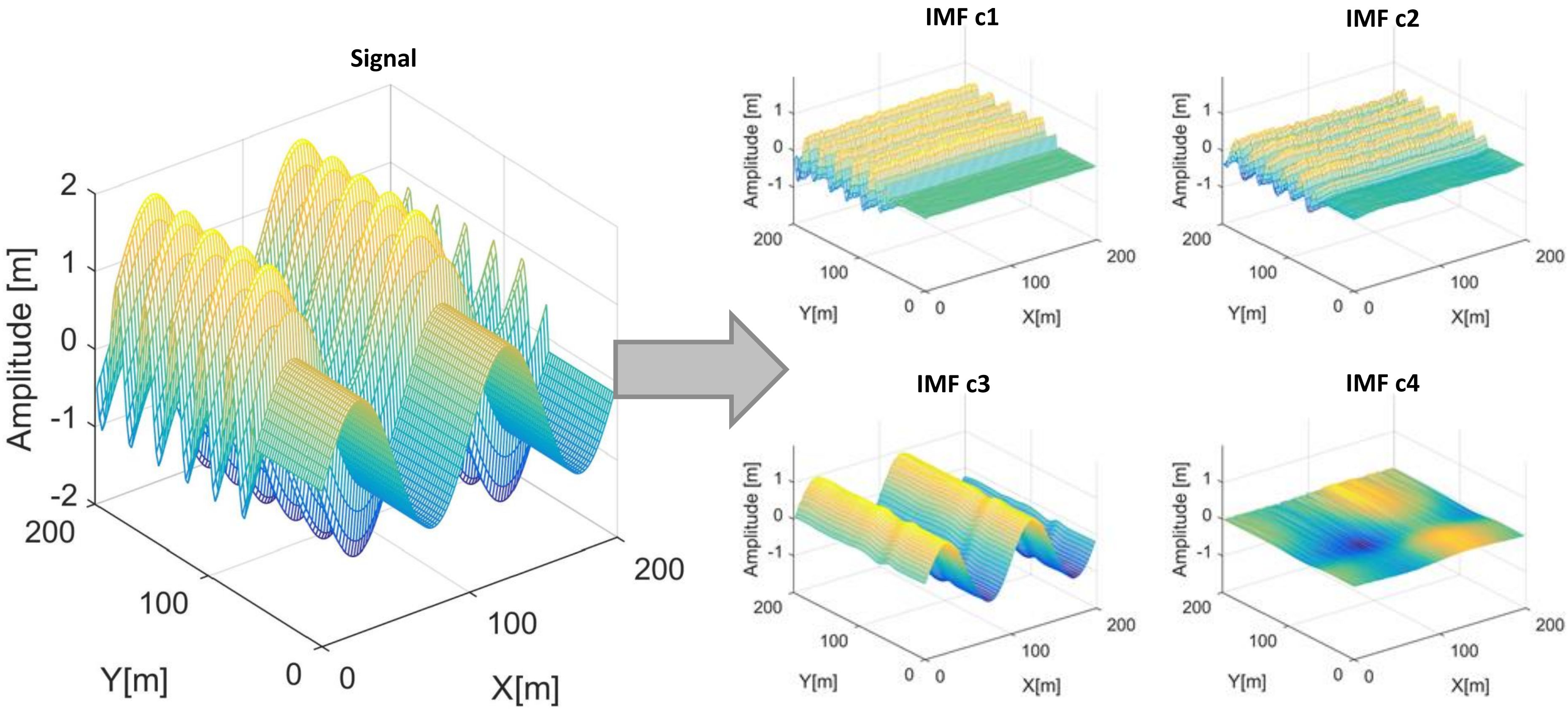
IMF c7



Hilbert Spectrum

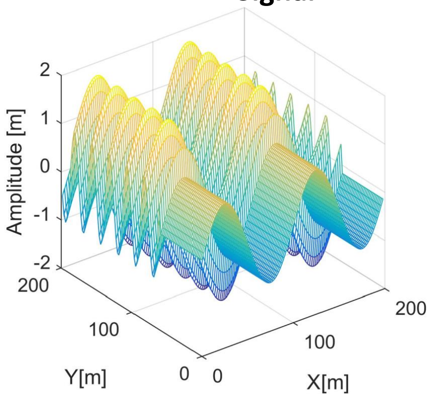
Aim of decomposition in MEEMD

Multidimensional Ensemble Empirical Mode Decomposition (MEEMD)
(Wu et al., 2009)

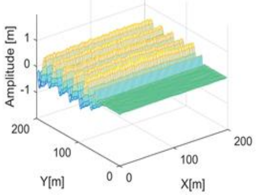


Procedure of MEEMD (3D HHT)

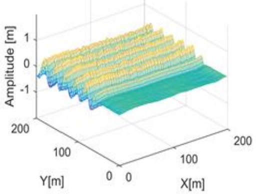
Signal



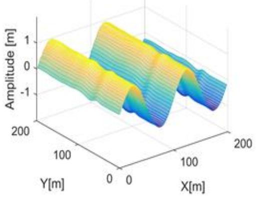
IMF c1



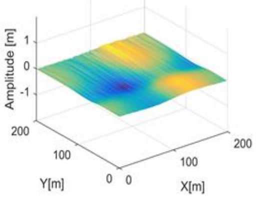
IMF c2



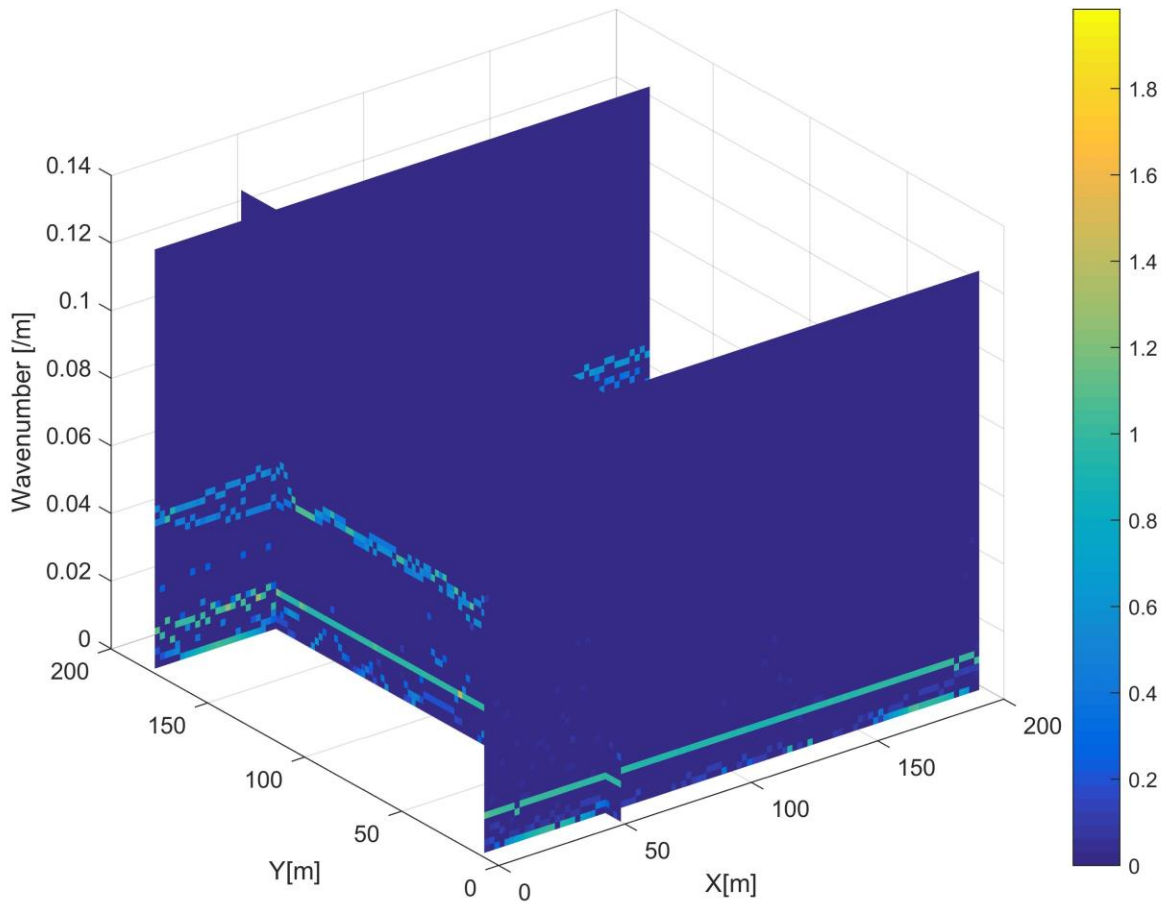
IMF c3



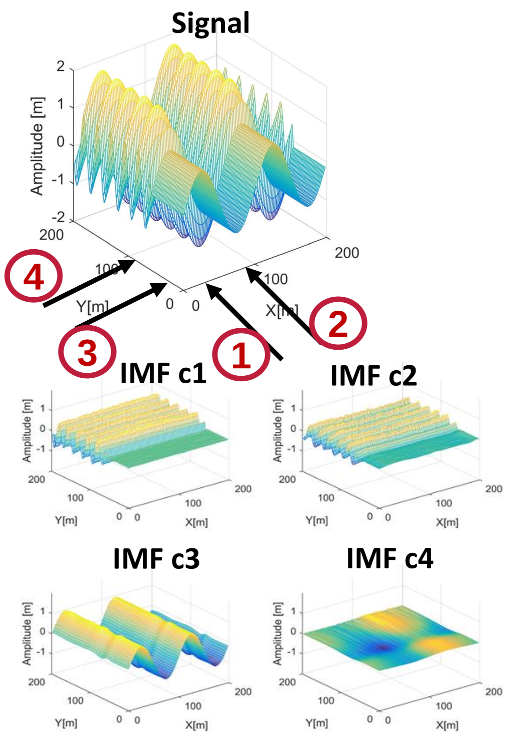
IMF c4

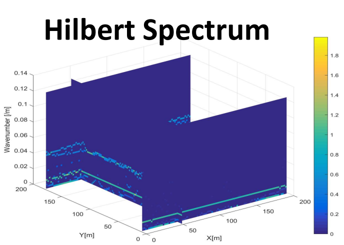


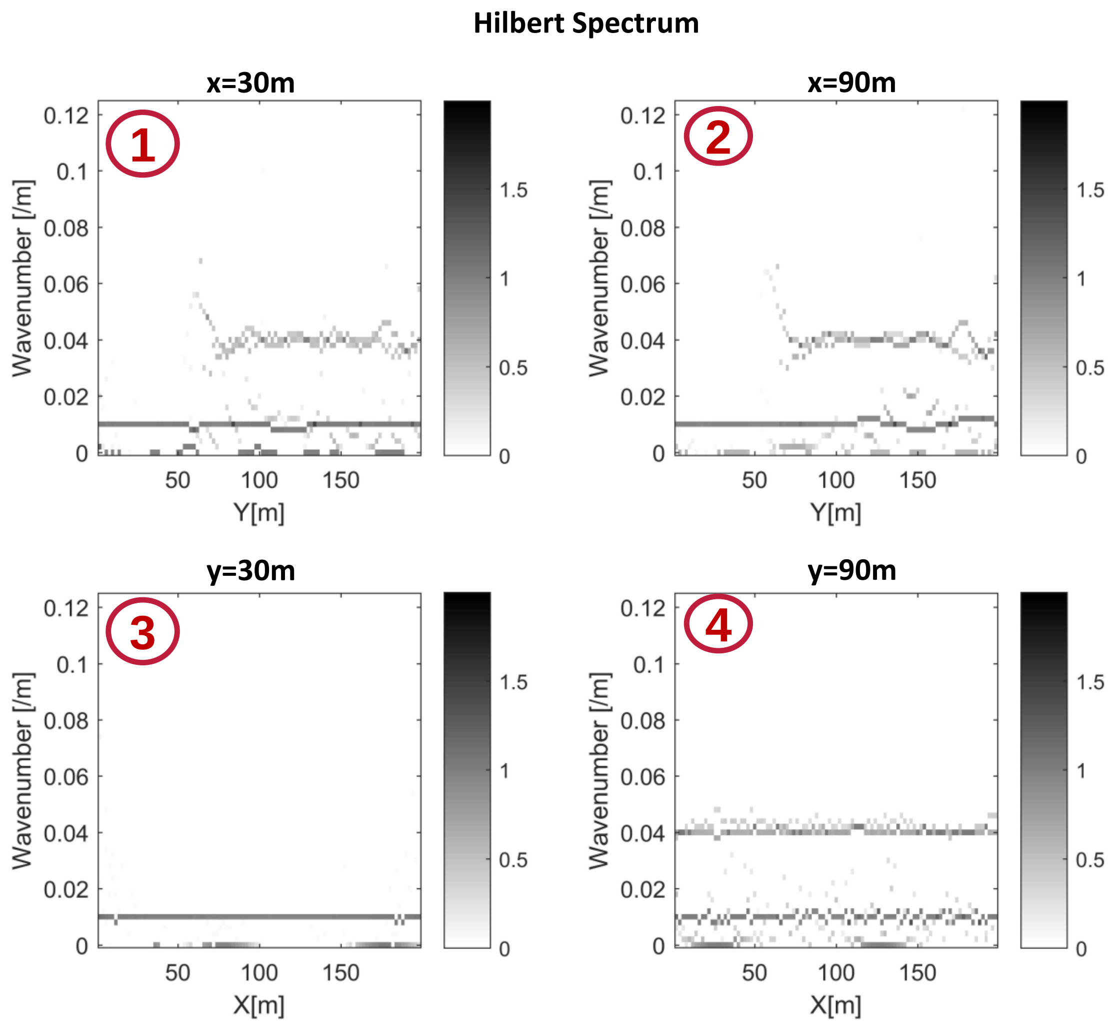
Hilbert Spectrum



Result of 3D HHT (MEEMD)

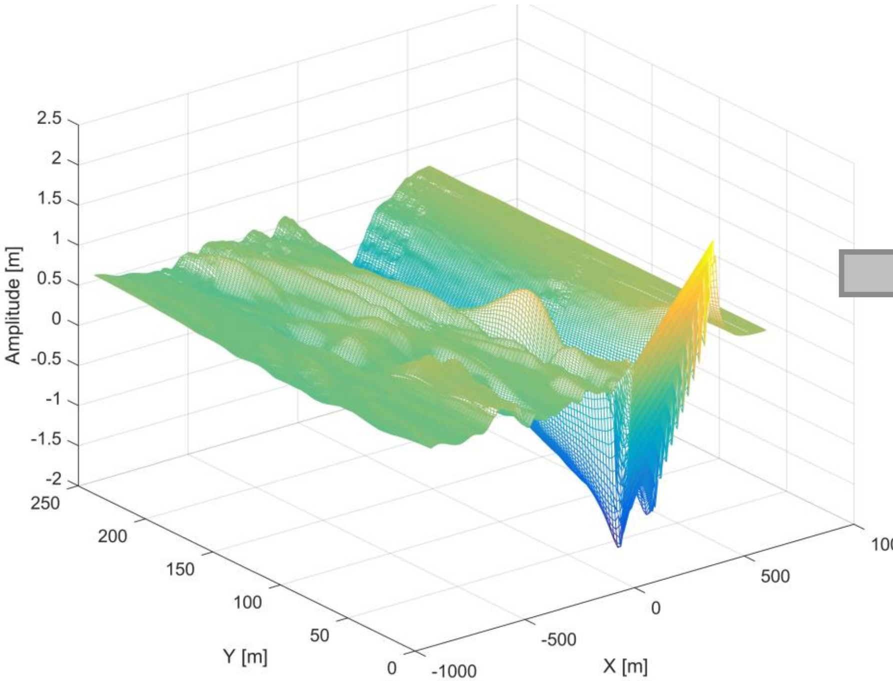






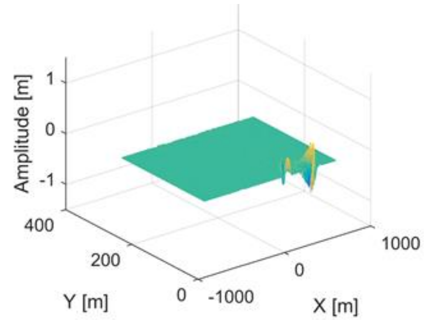
Application of 3D HHT to free-surface ship-wave field

Decomposition of 3D free surface into 3D IMF

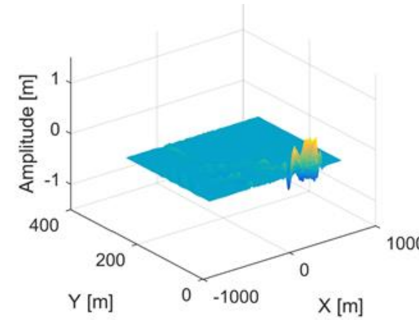


Free Surface

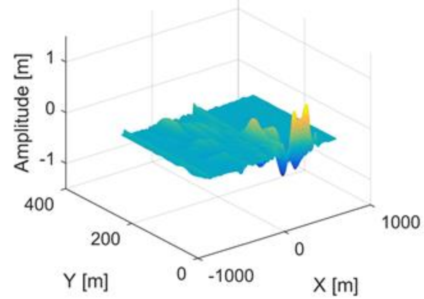
Intrinsic Mode Functions



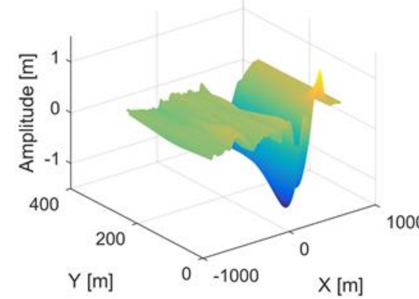
IMF c1



IMF c2

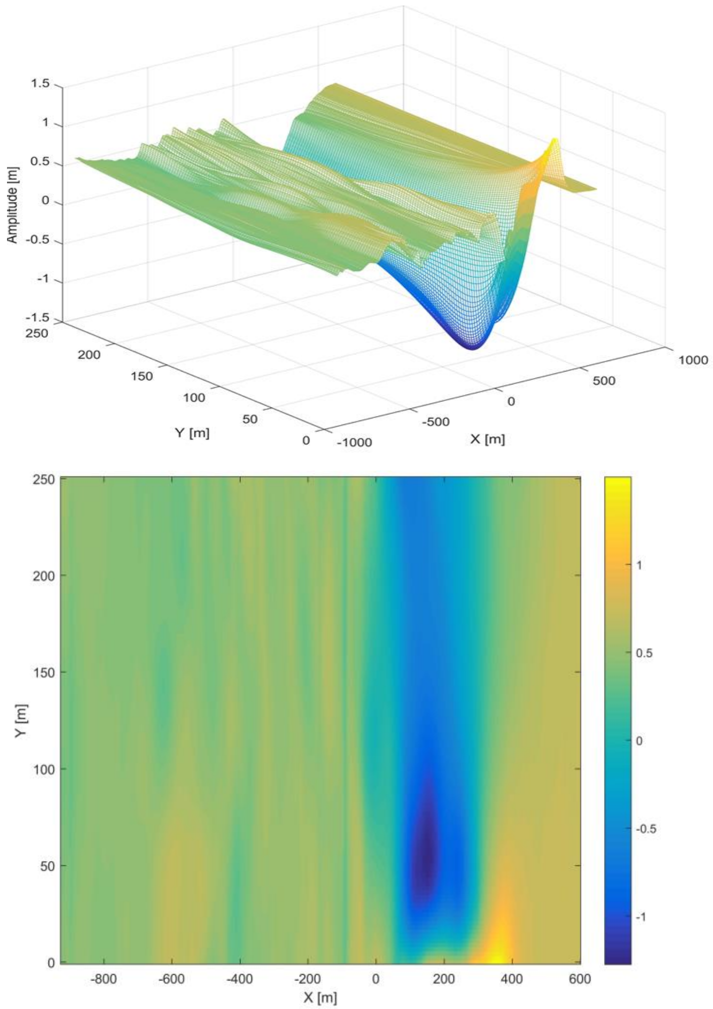


IMF c3

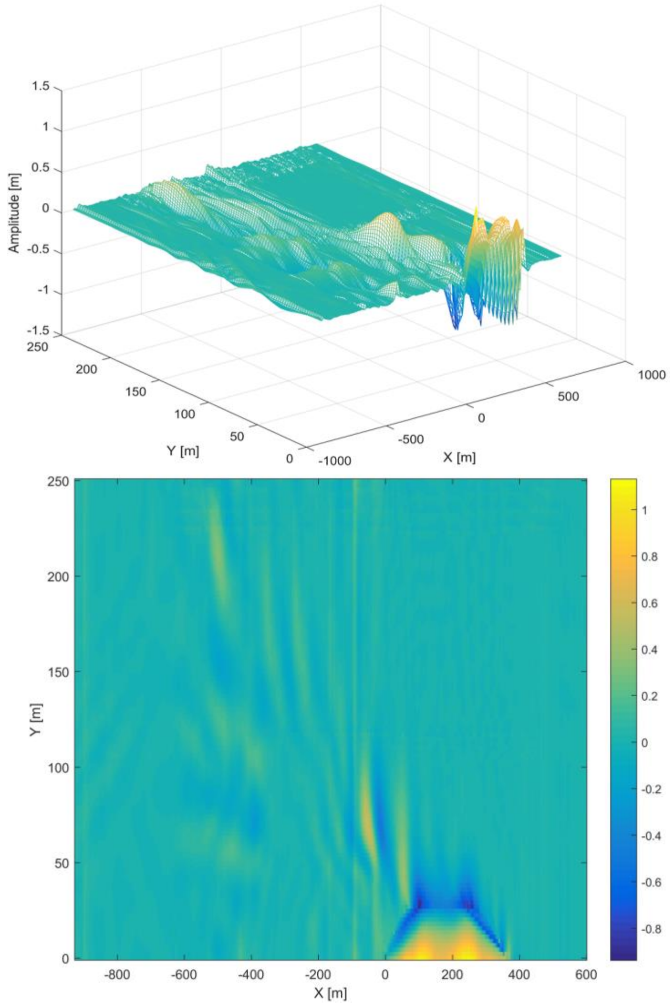


IMF c4

Separation of primary and secondary wave fields

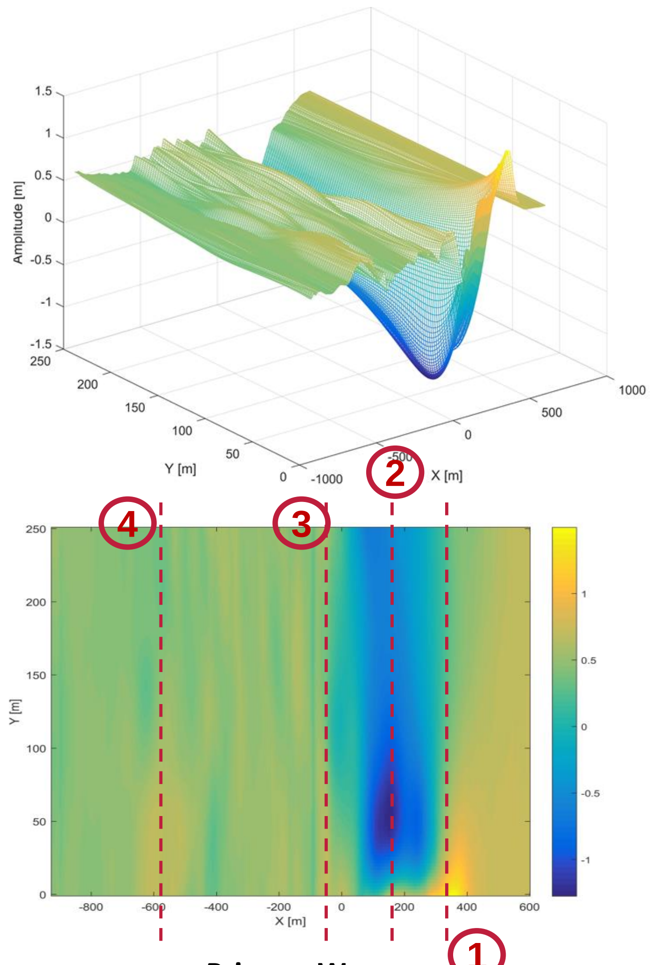


Primary Wave

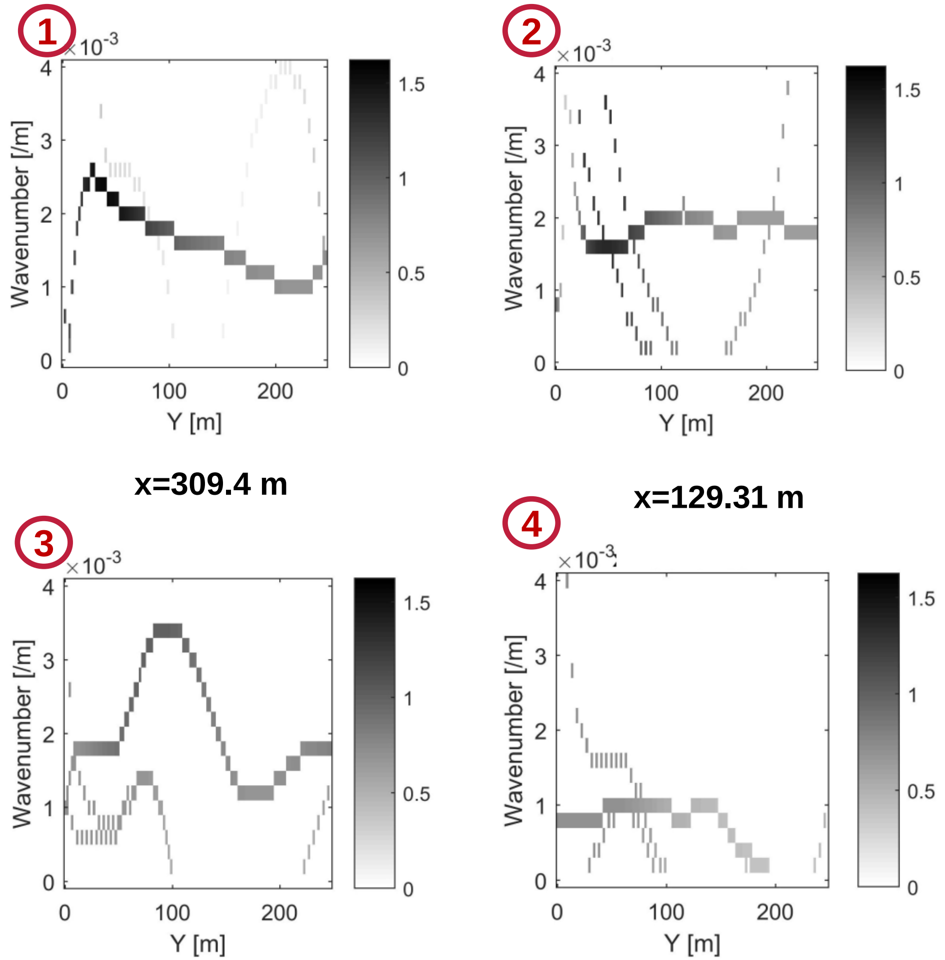


Secondary Wave

Hilbert spectra of primary wave as function of position x



Primary Wave



x=309.4 m

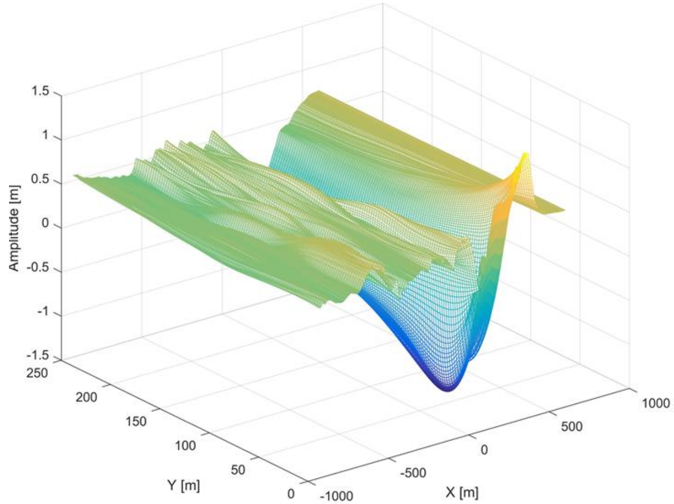
x=129.31 m

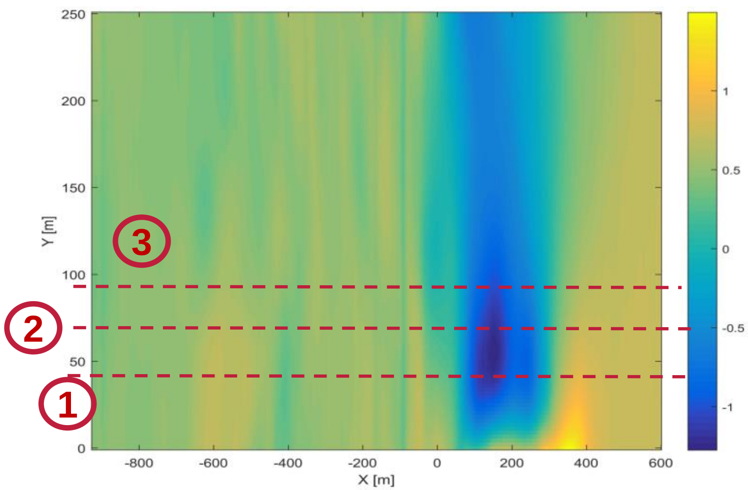
x=-50.78 m

x=-591 m

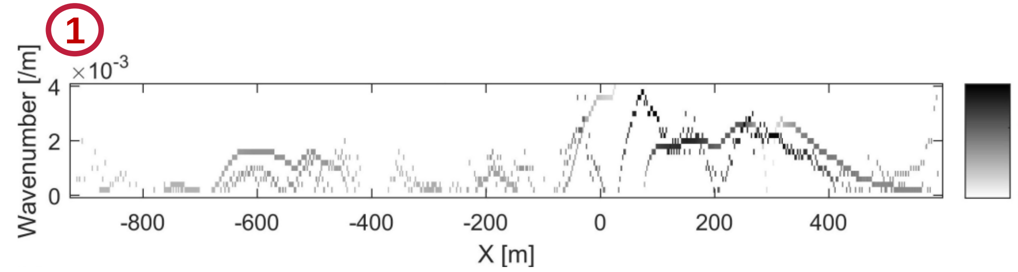
Hilbert spectrum of primary wave

Hilbert spectra of primary wave as function of position y

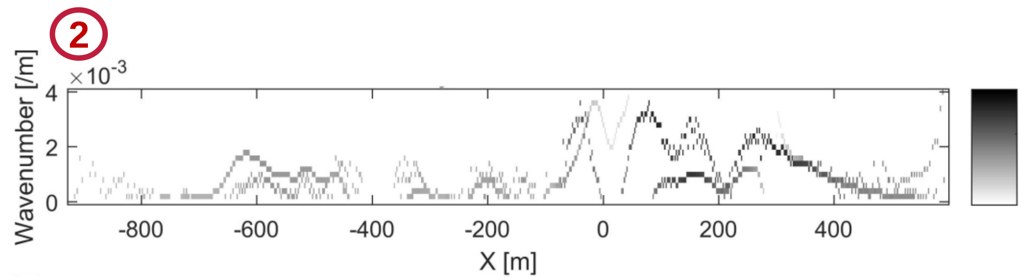




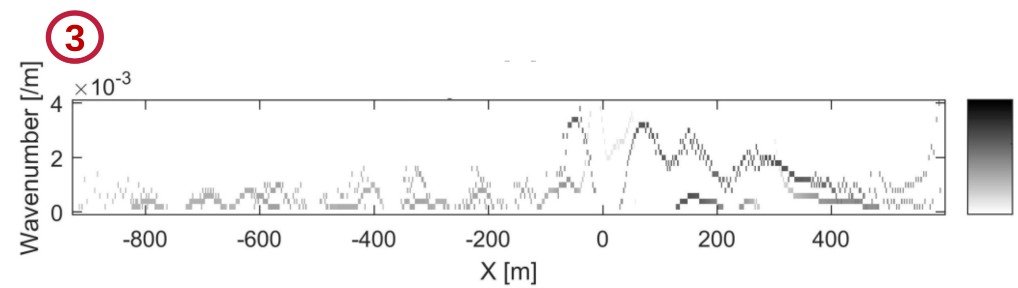
Primary Wave



y=45 m



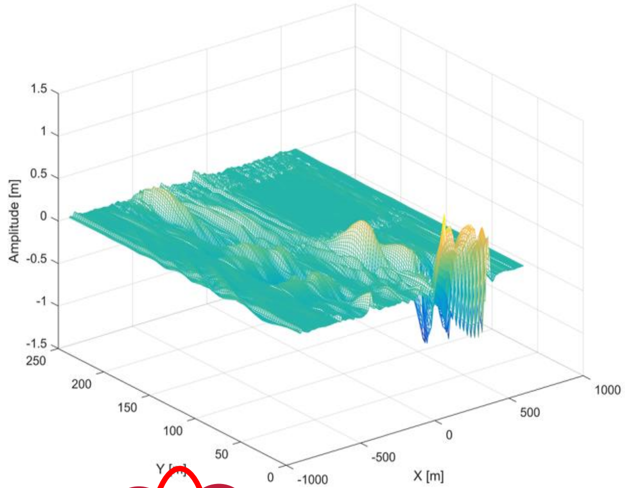
y=67.5 m

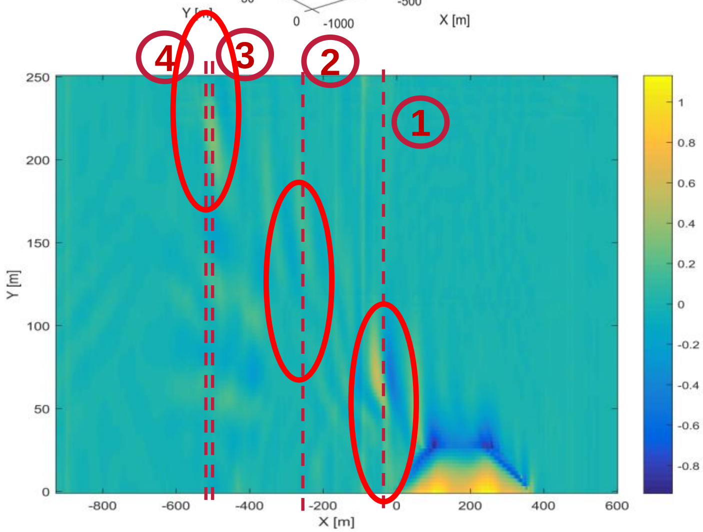


y=90 m

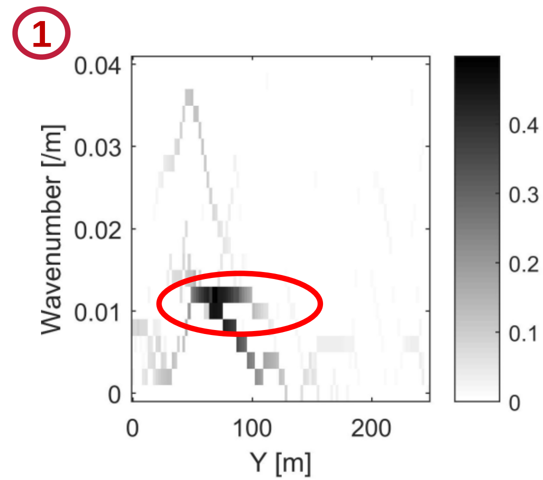
Hilbert spectrum of primary wave

Hilbert spectra of secondary wave as function of position x

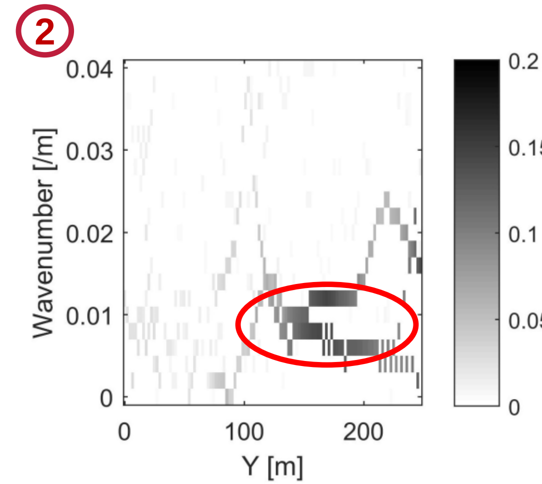




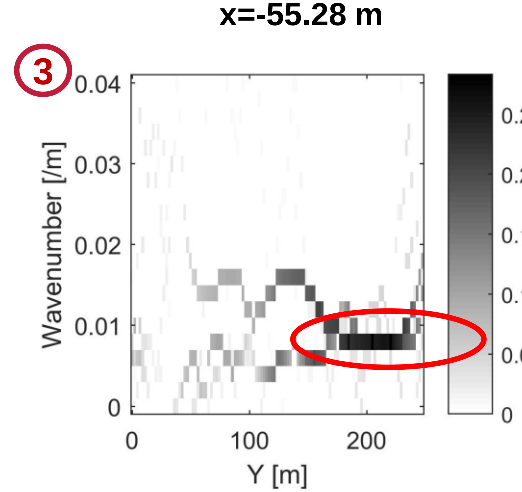
Secondary Wave



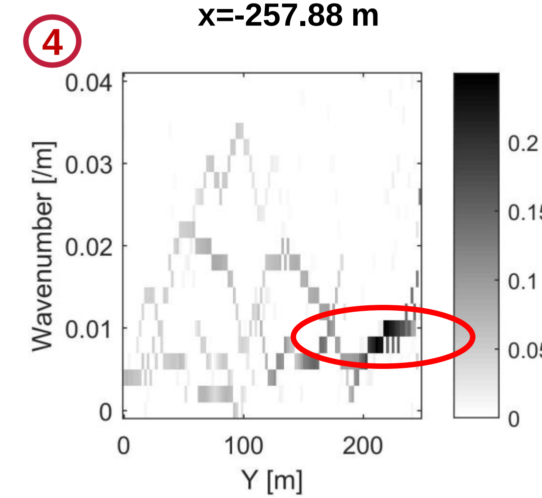
x=-55.28 m



x=-257.88 m



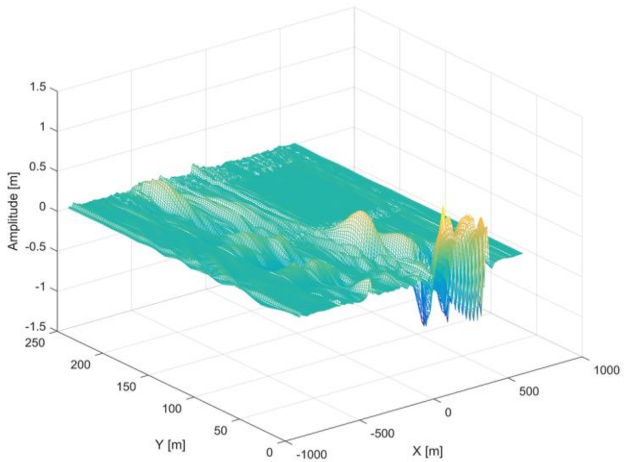
x=-494.25 m

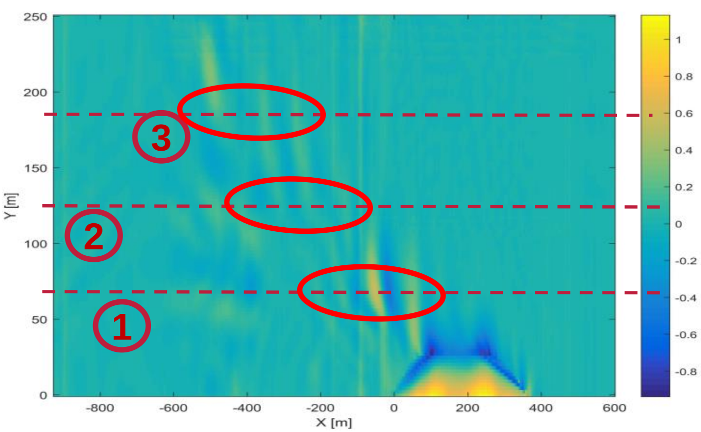


x=-523.51 m

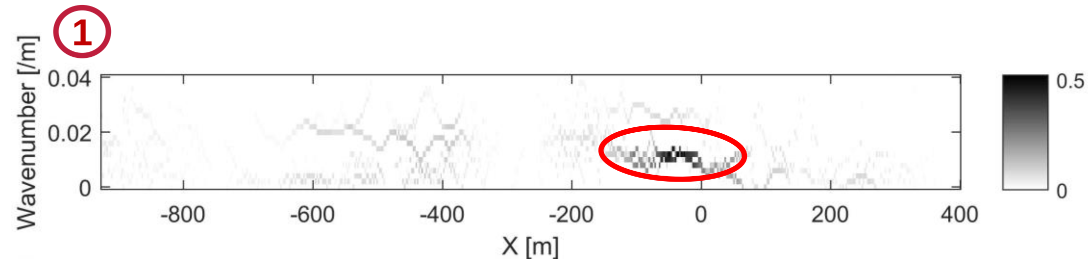
Hilbert spectrum of secondary wave

Hilbert spectra of secondary wave as function of position y

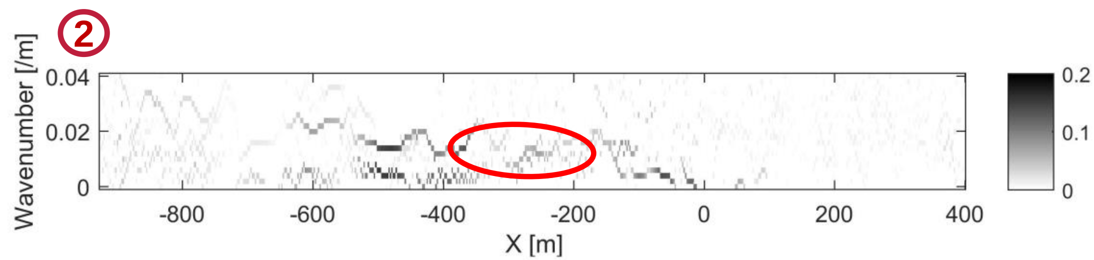




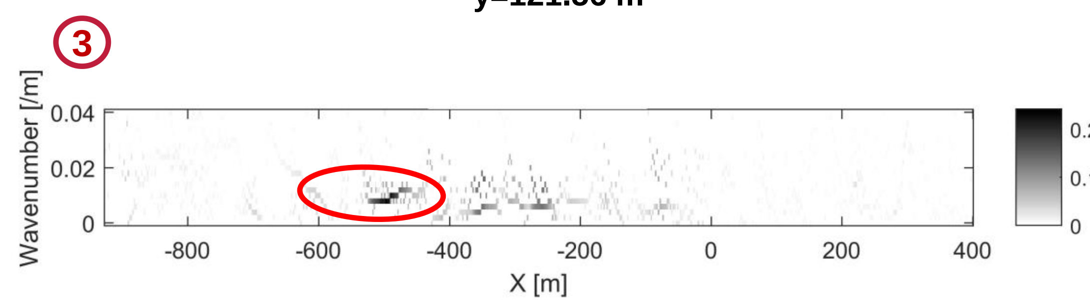
Secondary Wave



y=65.28 m



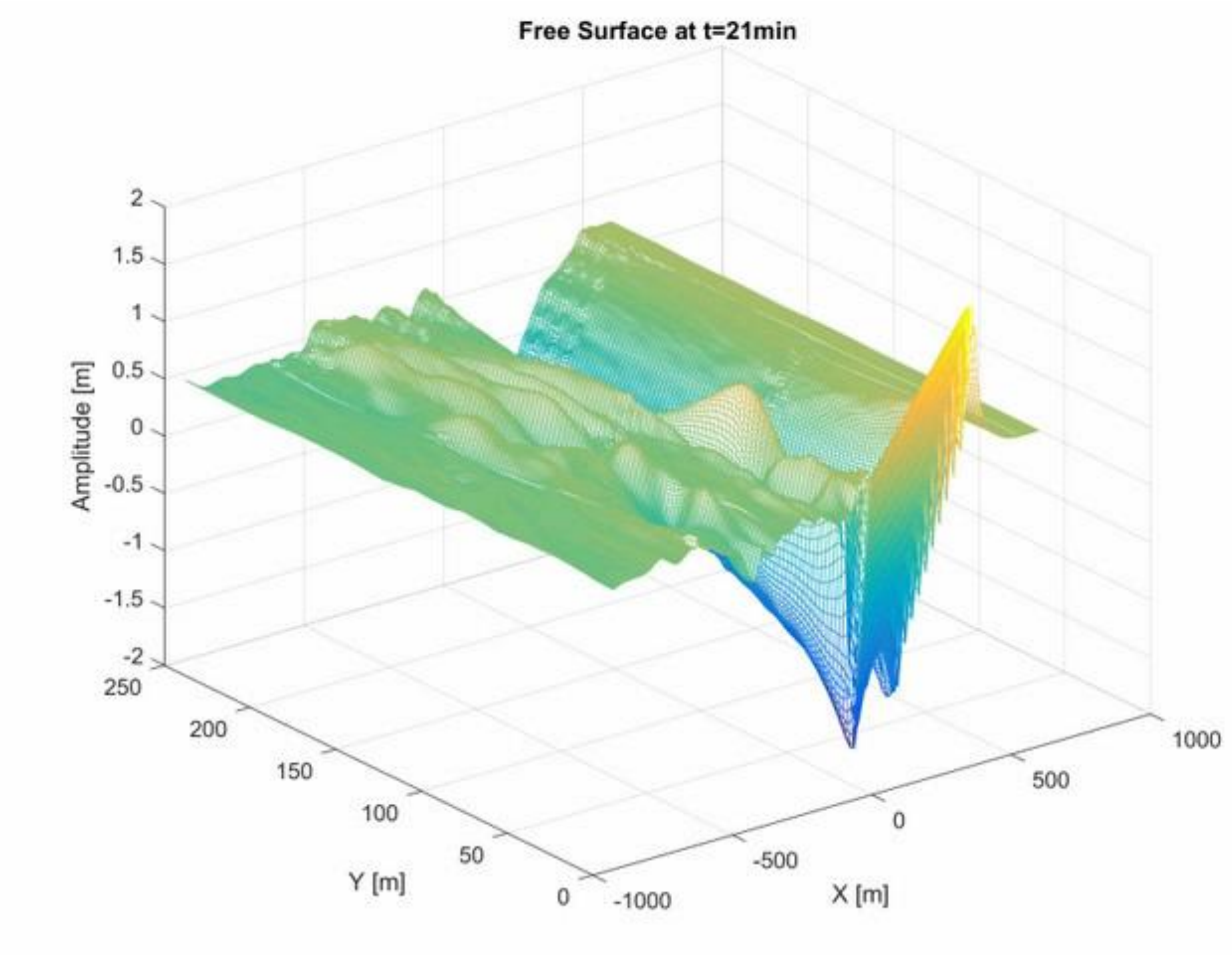
y=121.56 m



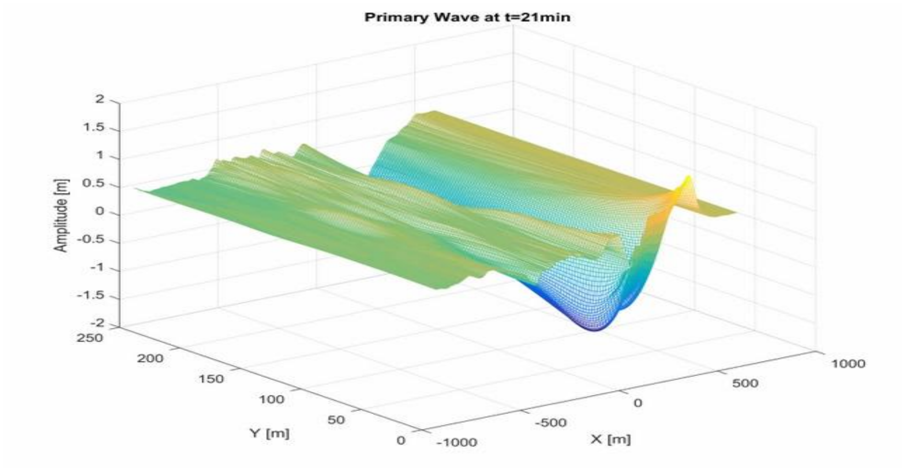
y=177.84 m

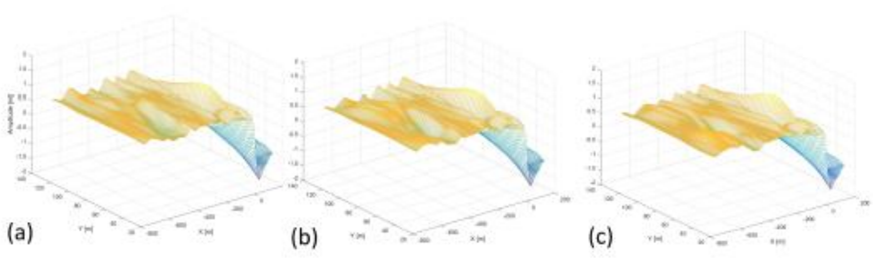
Hilbert spectrum of secondary wave

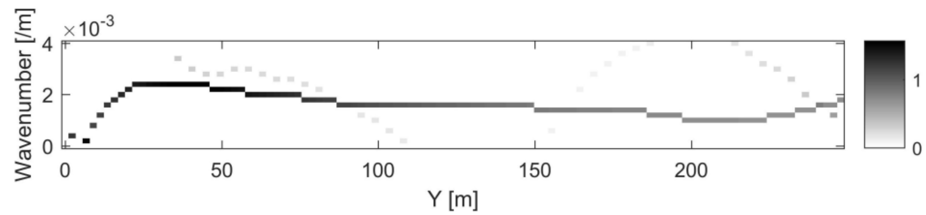
Temporal evolution of free surface



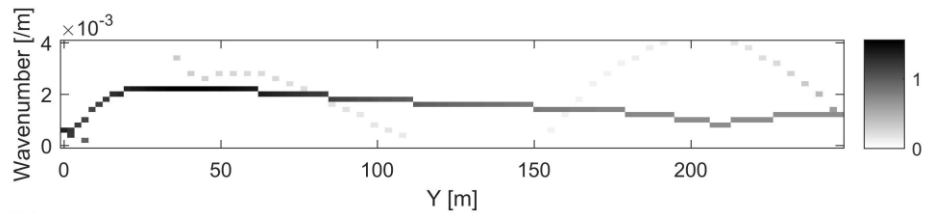
Analysis of primary wave at different time steps



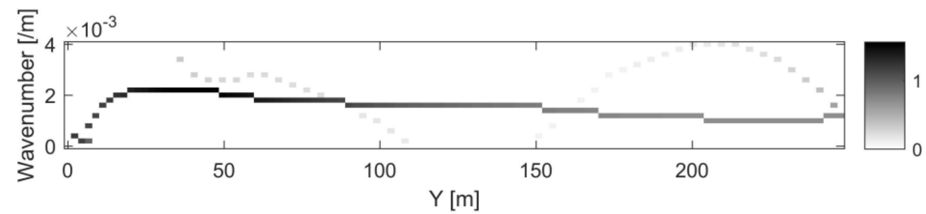




t=21 min



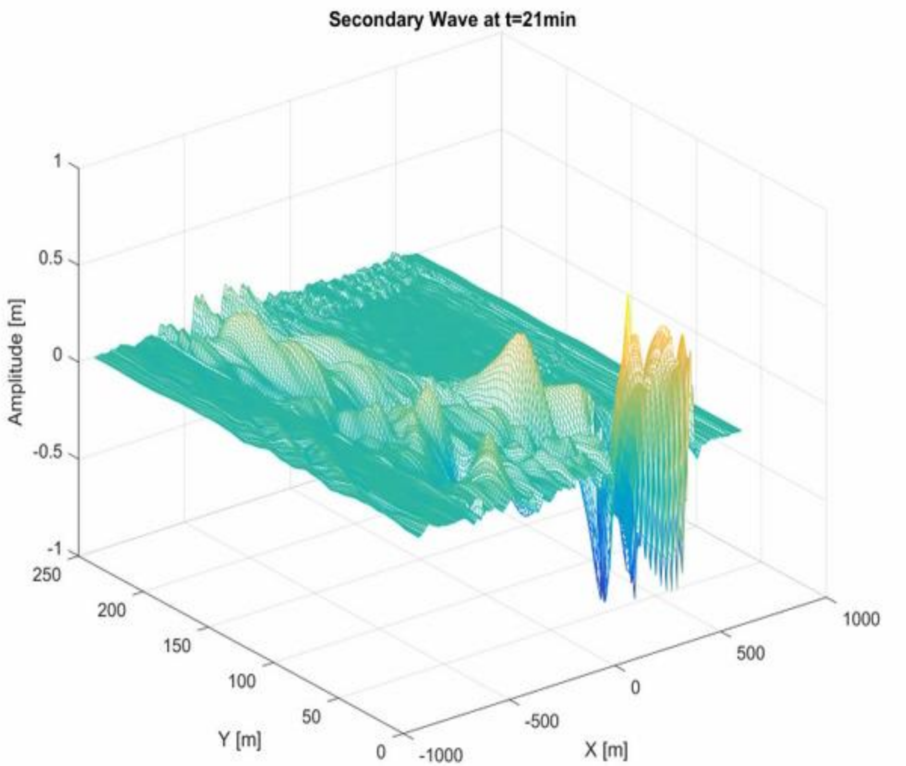
t=29 min

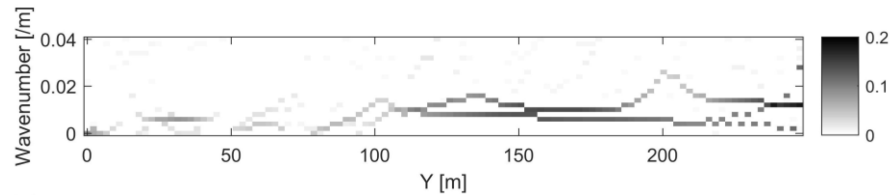


t=37 min

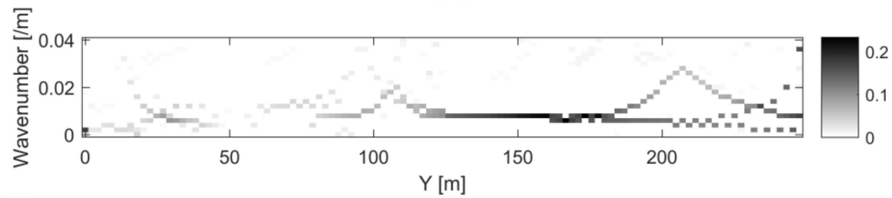
Hilbert spectrum of primary wave at x=309.4 m

Analysis of secondary wave at different time steps

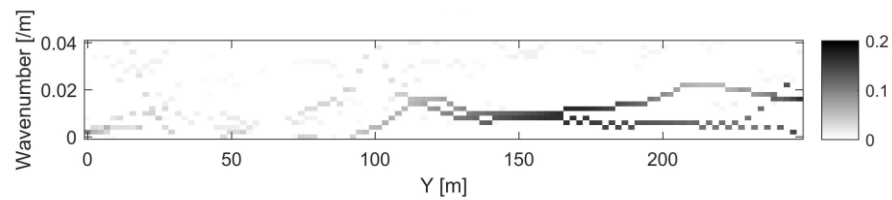




t=21 min



t=29 min



t=37 min

Hilbert spectrum of secondary wave at x=-257.88 m

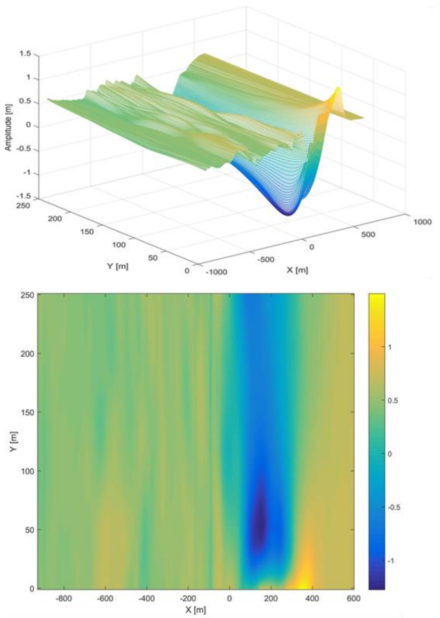
Conclusion

- Design approaches for bank structures in maritime waterways require input parameters for ship-induced waves at interface close to structures
- Input parameters can be derived from numerical simulations of evolving ship waves in 3D
- Analysis method required for decomposition of ship-wave field into long-period primary wave and short-period secondary waves
- MEEMD is successfully applied to show its capability to reliably decompose the different wave fields by frequency
- After separation, primary and secondary 3D wave fields can be analysed independently
- Further development and analysis required in order to increase performance and validate this method

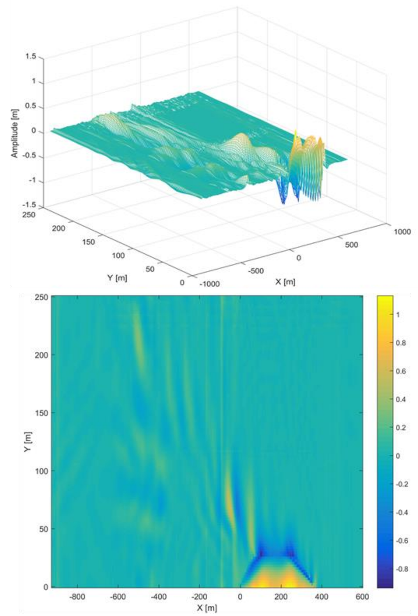
Furthermore:

- MEEMD is not limited to 3D ship-wave fields…

Thank you for your attention!



Primary Wave



Secondary Wave

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German Research Foundation

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