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The State of the Art and Science of Coastal Engineering

Finding Bichromatic-Bidirectional Waves With ADV

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COPPE UFRJ

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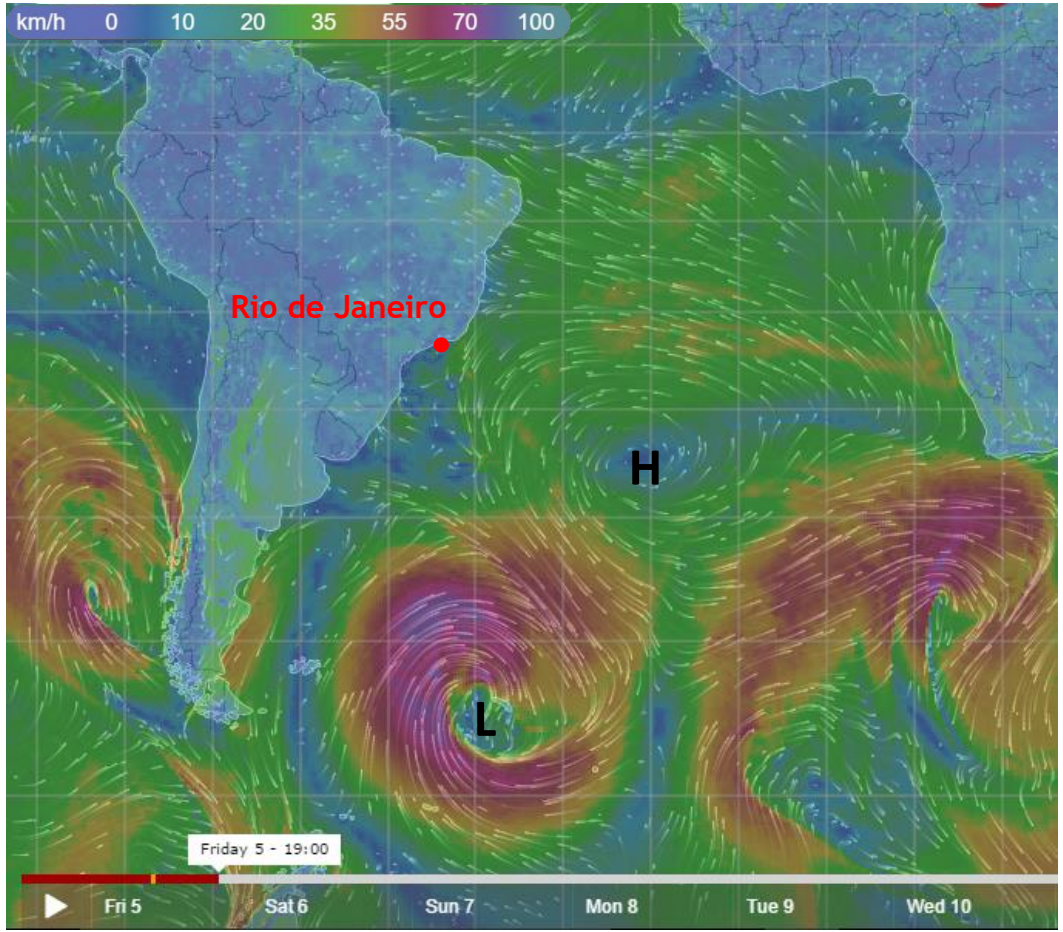
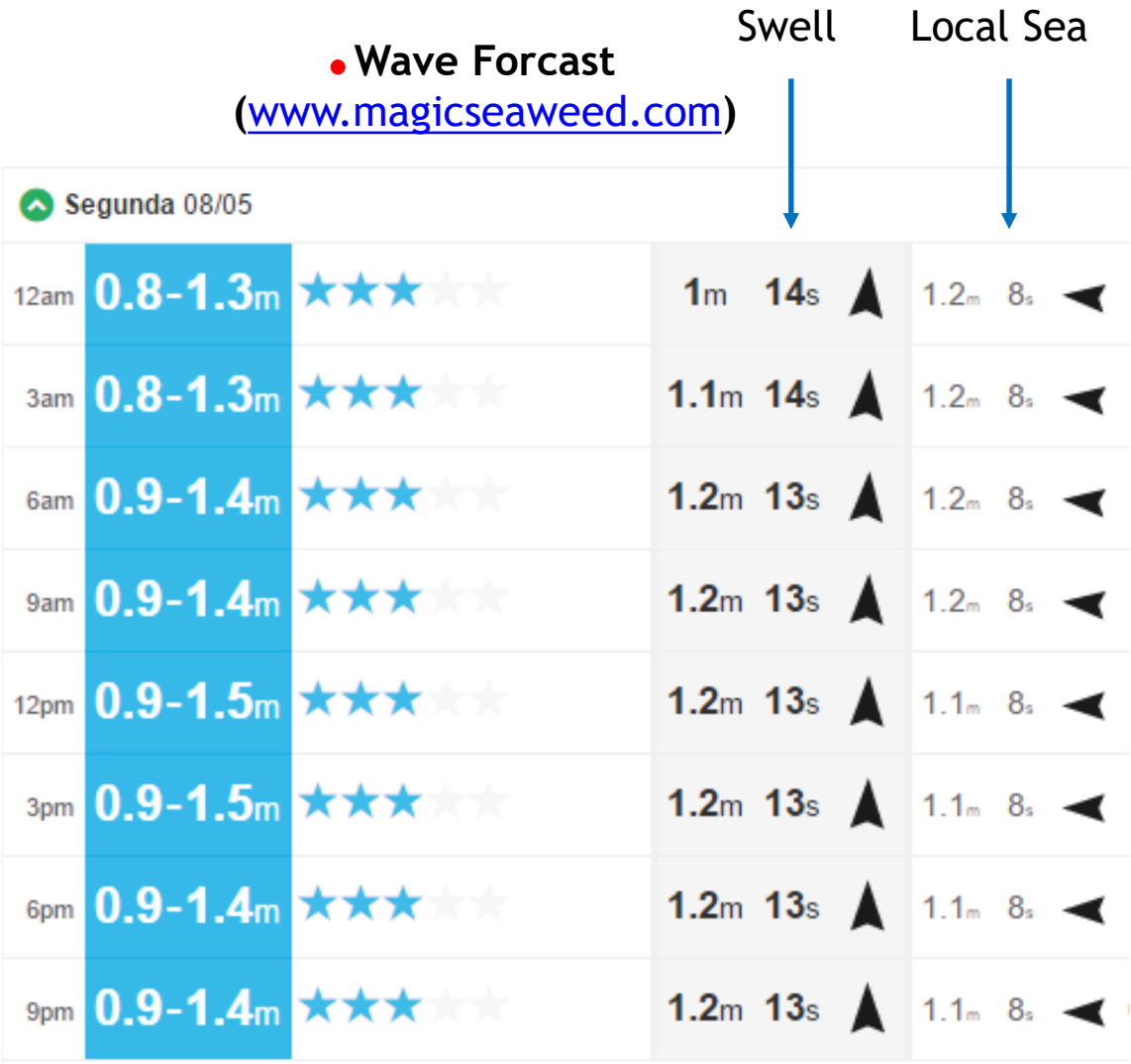
Objectives

- **General idea:** understand better what happens during bimodal sea states;

Wind chart
(www.windy.com)

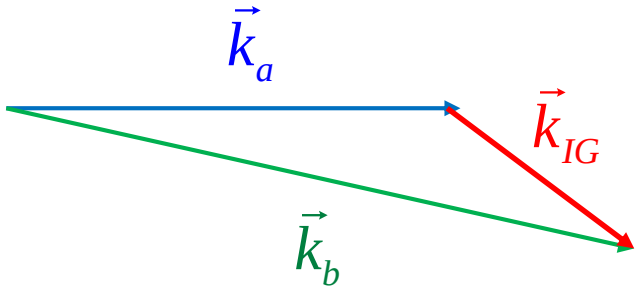


Wave Forcast
(www.magicseaweed.com)

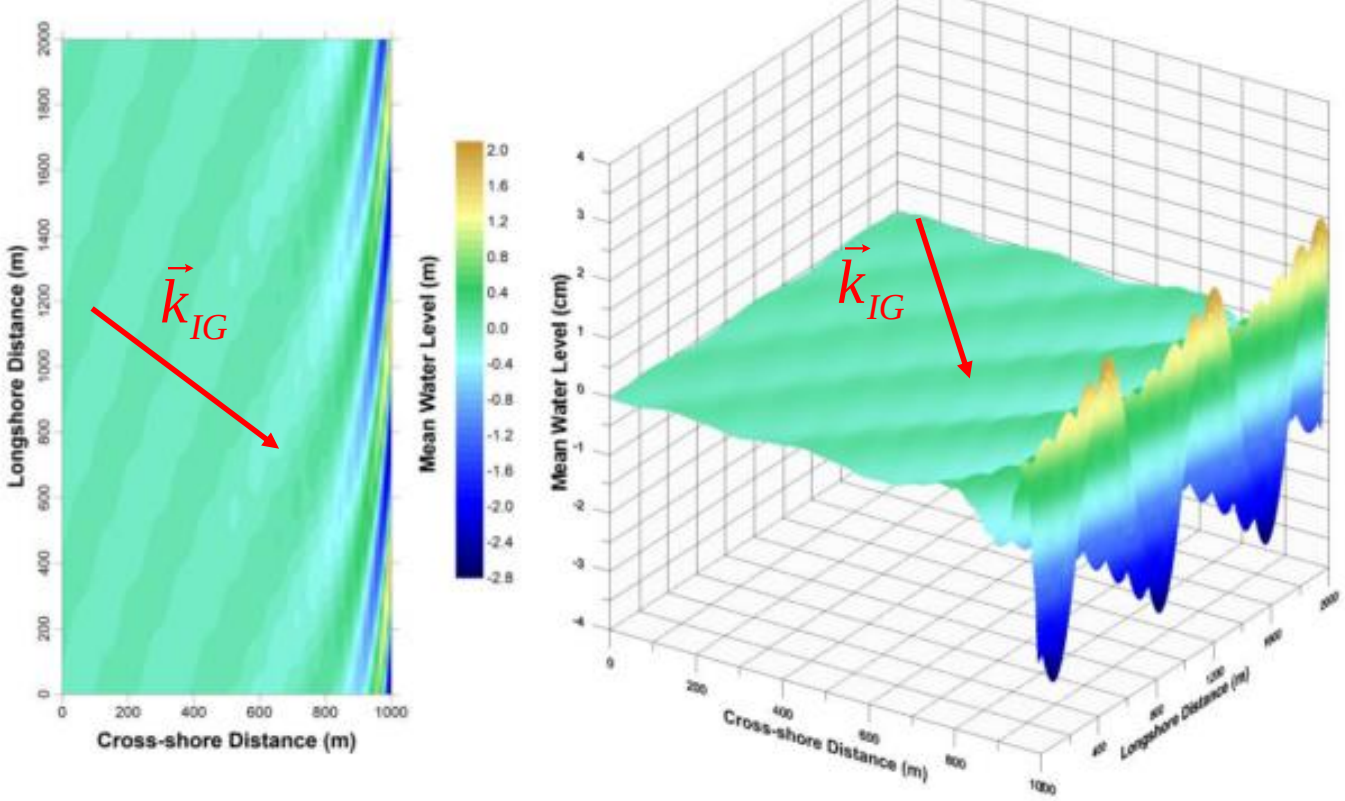


Objectives

- **General idea:** understand better what happens during bimodal sea states;
- **Core of the research:** identify better the infragravity wave (2nd order nonlinear wave-wave interaction);



Infragravity Wave



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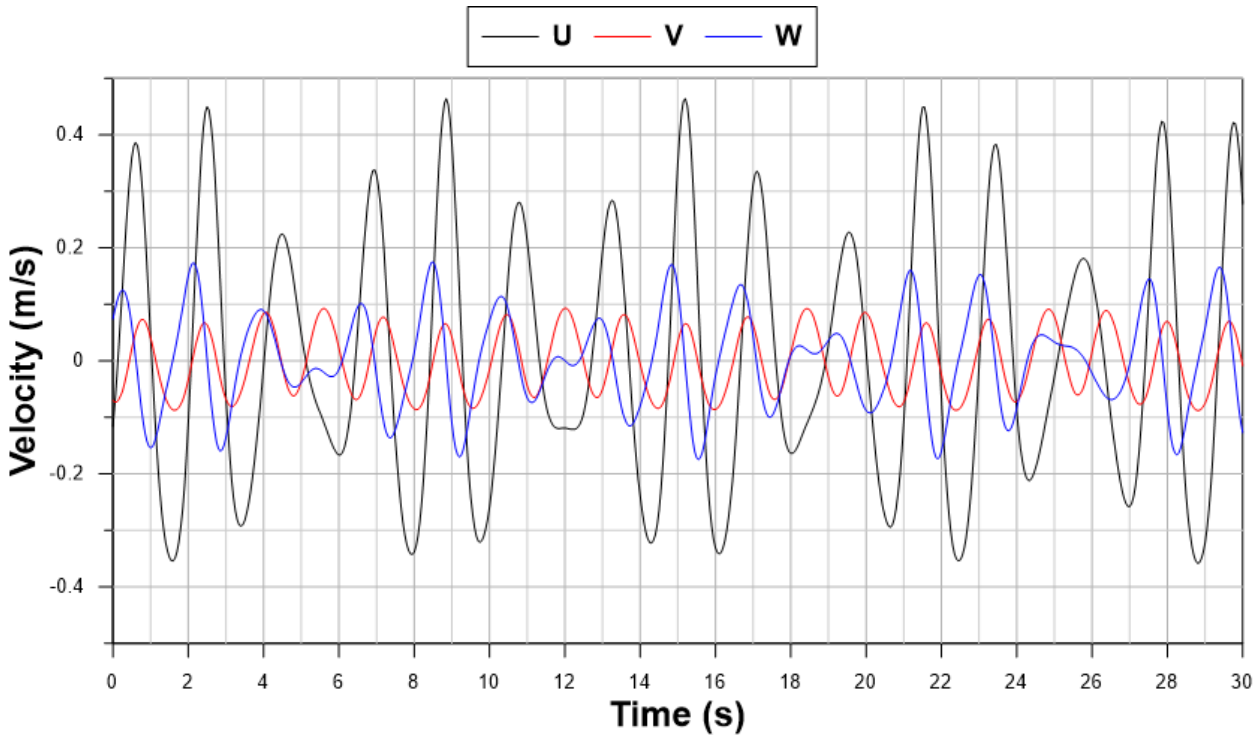
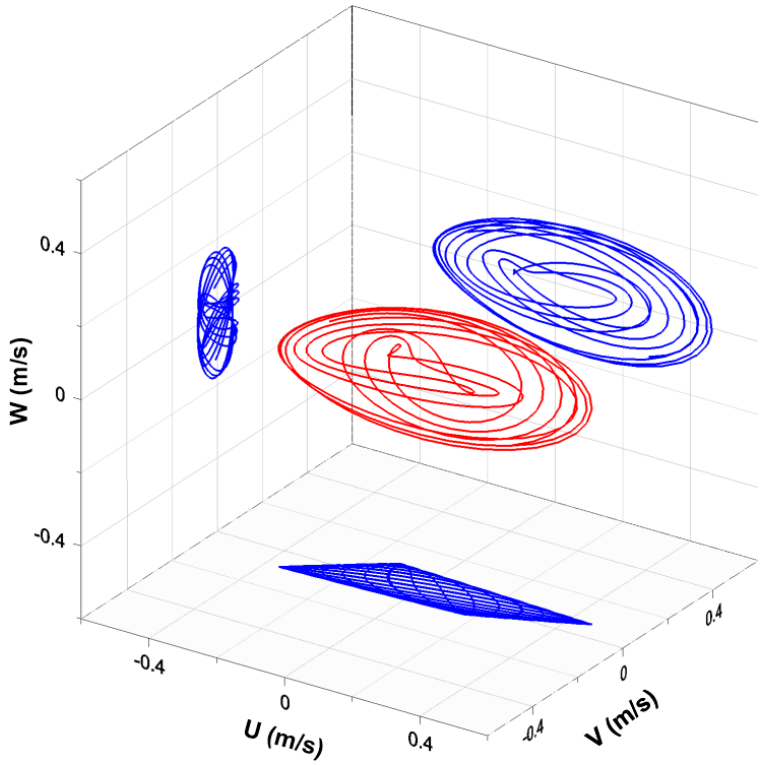
- **Main instrument:** ADVs (velocity x height);

Theoretical Time Series



Theoretical Orbital Velocity (Hodograph)



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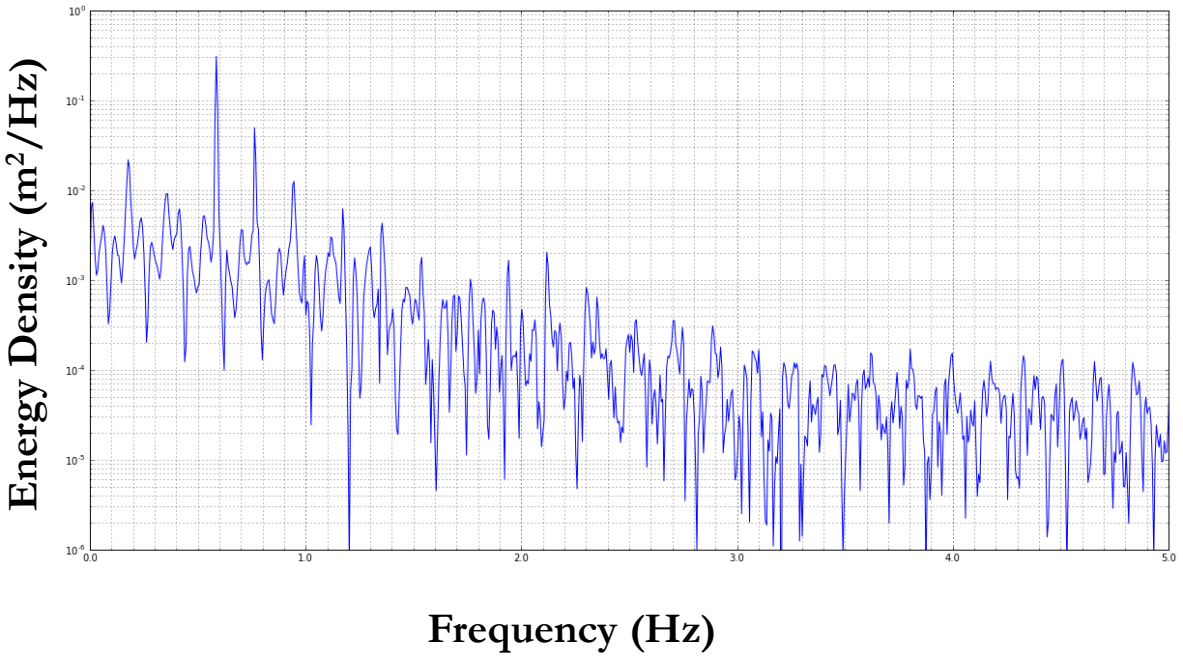
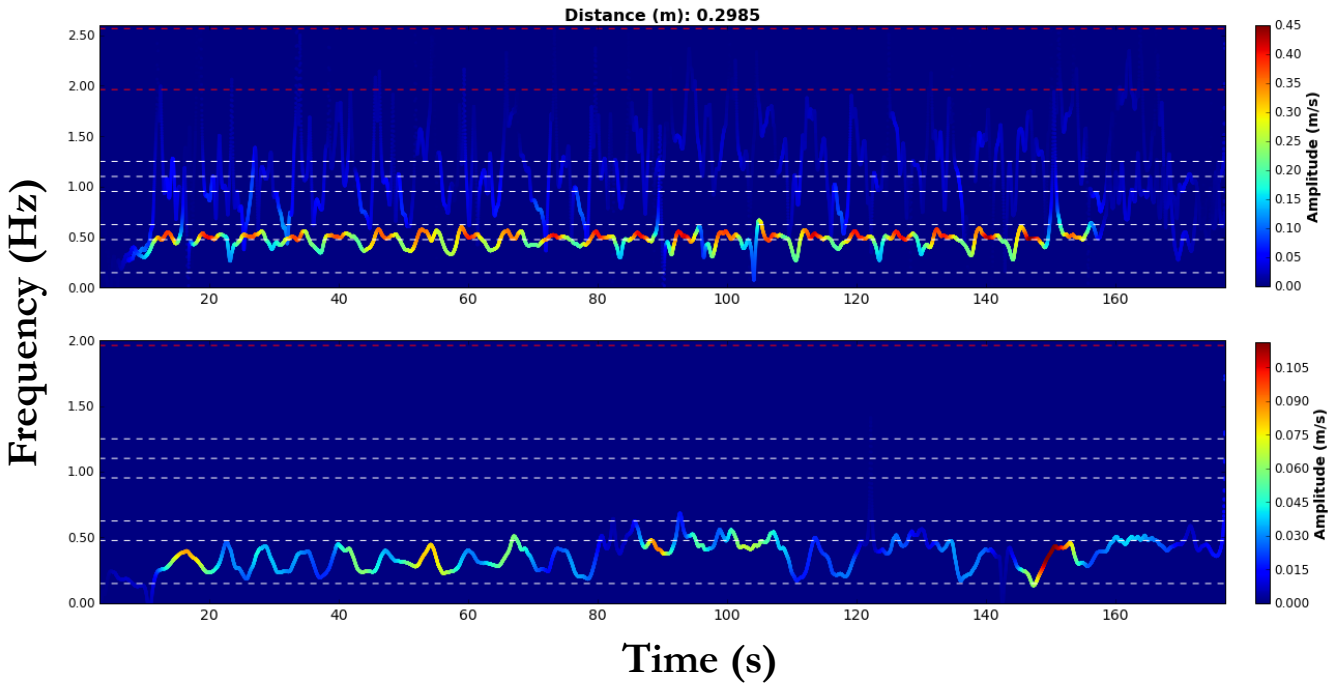
- **Data analysis method:** HHT (Hilbert-Huang Transform);

FFT

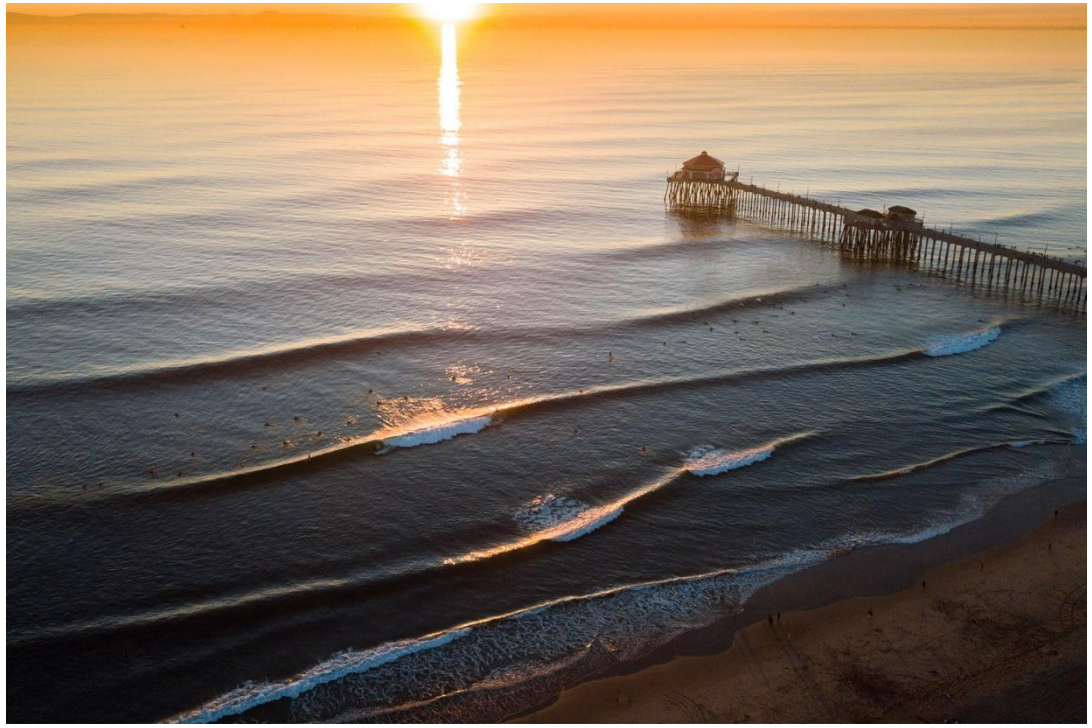


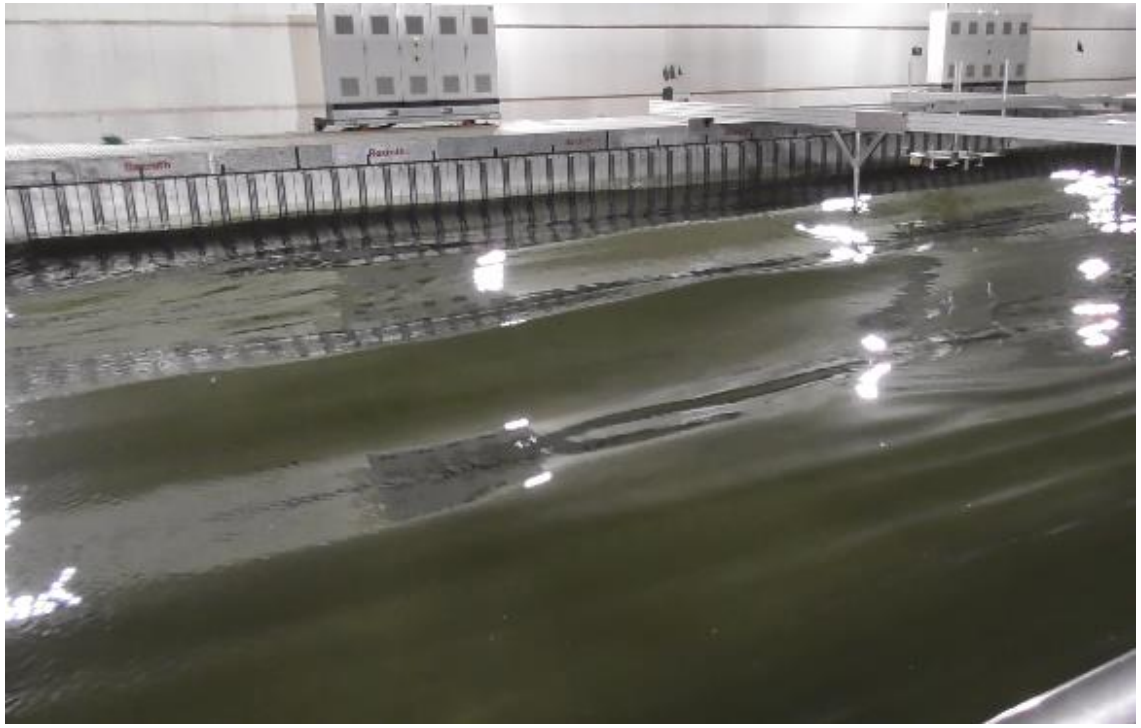
HHT



Objectives

- **General idea:** understand better what happens during bimodal sea states;
- **Core of the research:** identify better the infragravity wave (2nd order nonlinear wave-wave interaction);
- **Main instrument:** ADVs (velocity x height);
- **Data analysis method:** HHT (Hilbert-Huang Transform);
- **Essential simplification:** Bichromatic-Bidirectional (Bi-Bi) waves.





Pat Nolan (www.patnolanphoto.com)

Experiments

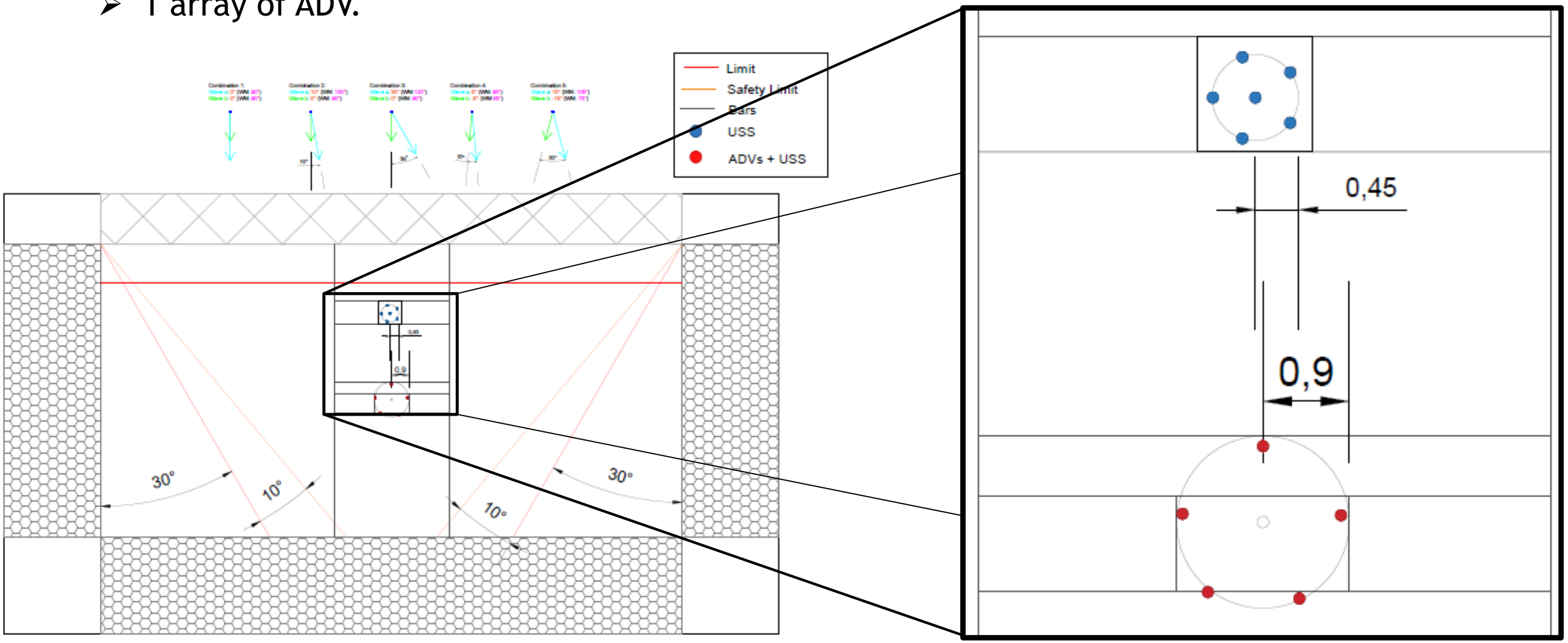
- **Leibniz Universität Hannover:**

Ludwig-Franzius-Institute
for Hydraulic, Estuarine and
Coastal Engineering

Multidirectioanl Wave Basin	
. Length:	40 m
. Width:	25 m
. Depth:	1 m
. Max. wave height:	0.47 m
. Wave board:	72 individual piston boards
. Directional spreading:	5° to 175°
. Waves:	regular and irregular, reproduction of in-situ measurements

Experiments

- **Instruments positioning:**
  - 2 arrays of wave gauges;
  - 1 array of ADV.



Experiments

- **Total of 271 tests;**

Test	h (m)	d/h (%)	H (cm)	T (s)	D (°)
271	2 different depths (0.60, 0.75)	2 diferente ADV elevations (47, 58)	Combination of 2 different Heights (5 – 16)	Combination of 3 different periods (1.1 – 3.0)	Combination of 3 different angle deltas (0, 10, 30)

Experiments

- Total of 271 tests;
- **Tests (h = 0.75 m):**
  - Wave 'a': H = 0.10 m / T = 1.3 s
  - Wave 'b': H = 0.16 m / T = 1.7 s

Test	h (m)	d/h (%)	H (cm)	T (s)	D (°)
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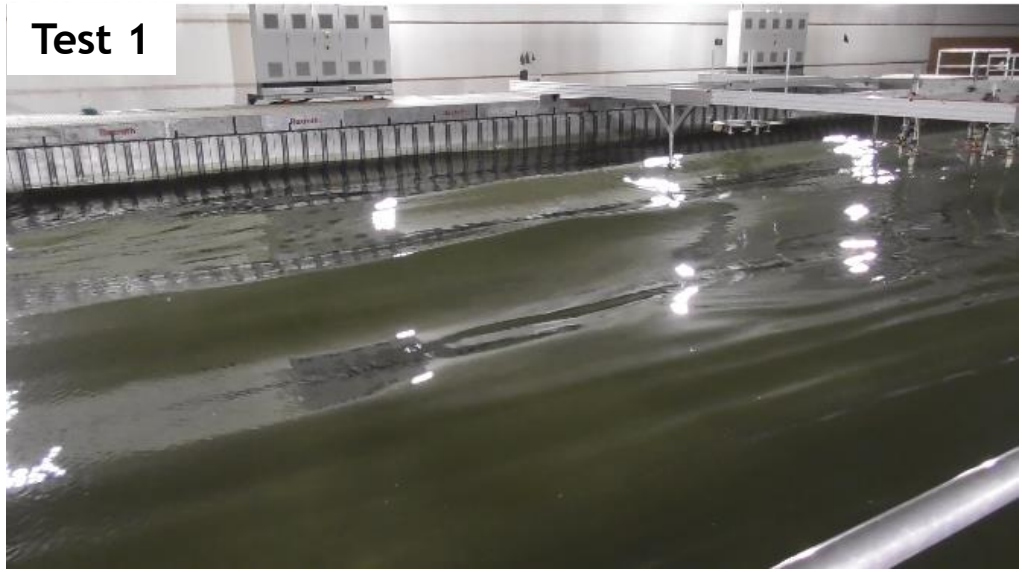
Test	ΔD (°)	Da (°)	Db (°)	ADV Depth (cm)
1	10	10	0	35
2	10	10	0	50
3	10	5	-5	35
4	30	30	0	35

Test 1

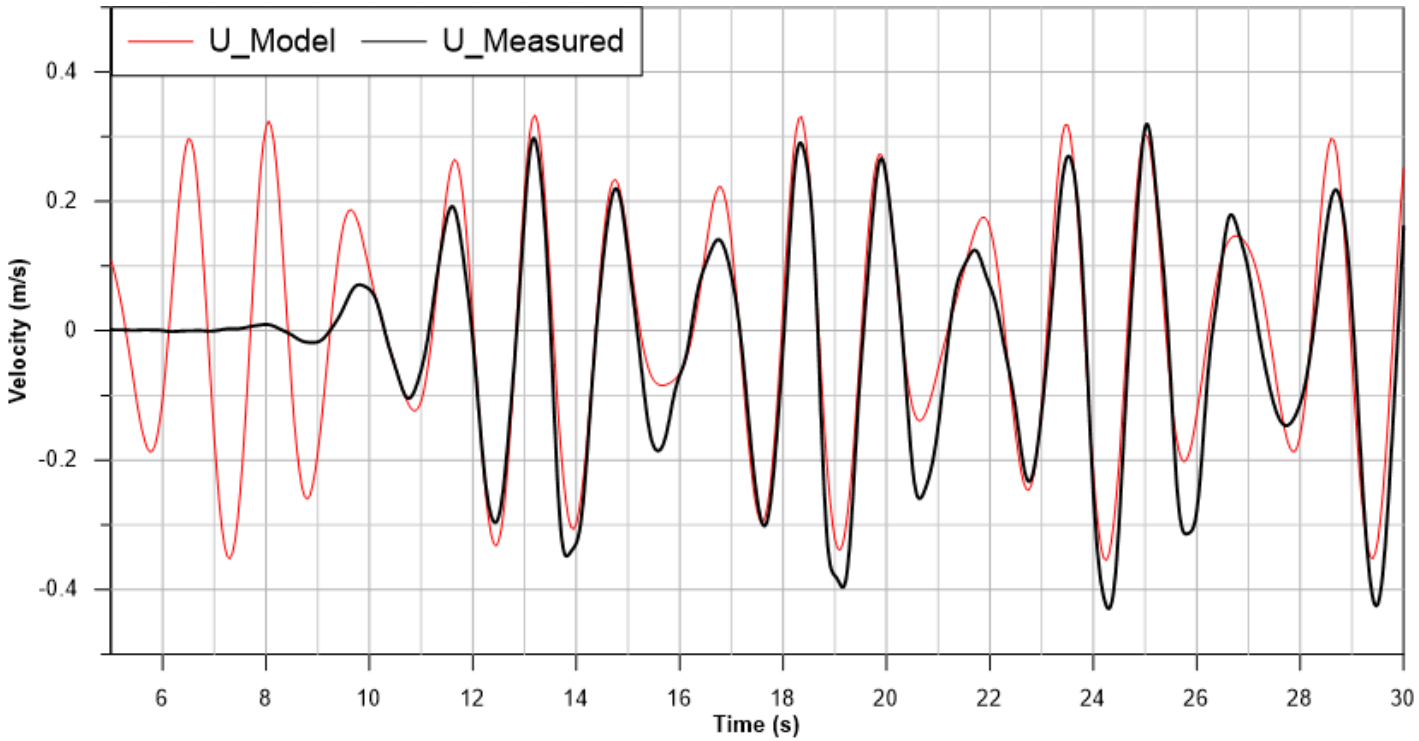


Test 4

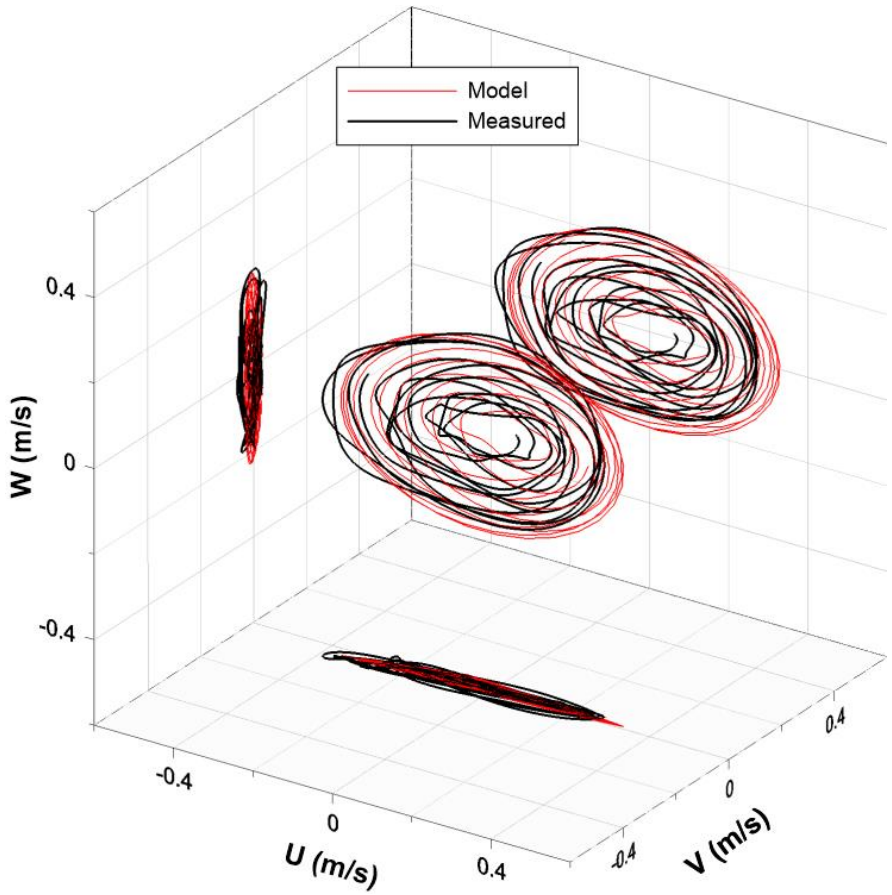
Methodology

- **Step 1: Data quality:** seeding material (TiO_2 + circular source);
- **Step 2: Despike method:** Goring and Nikora (2002);
- **Step 3: Thompson filter:** Thompson (1983);
- **Step 4: ADV tilt correction:** Neves *et al.* (2012).
- **Final result:**

Horizontal U Velocity

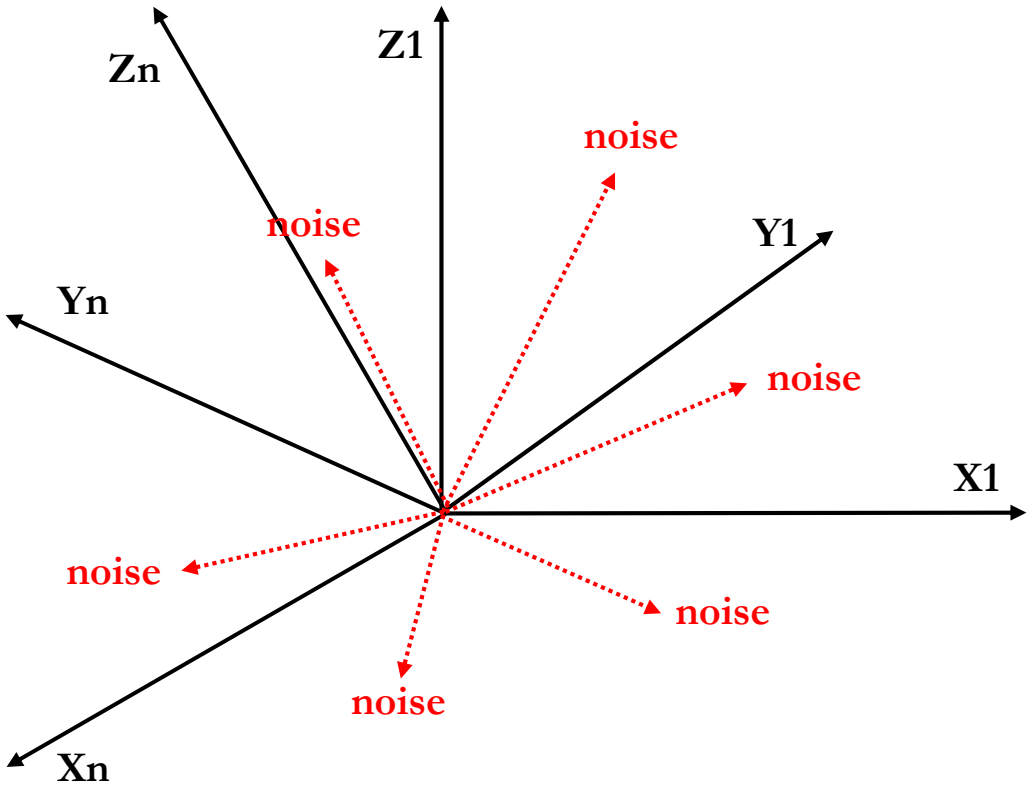


Orbital Velocity



Data Analysis

- **HHT** (Hilbert-Huang Transform):
  - **MEMD** (Multivariate EMD)



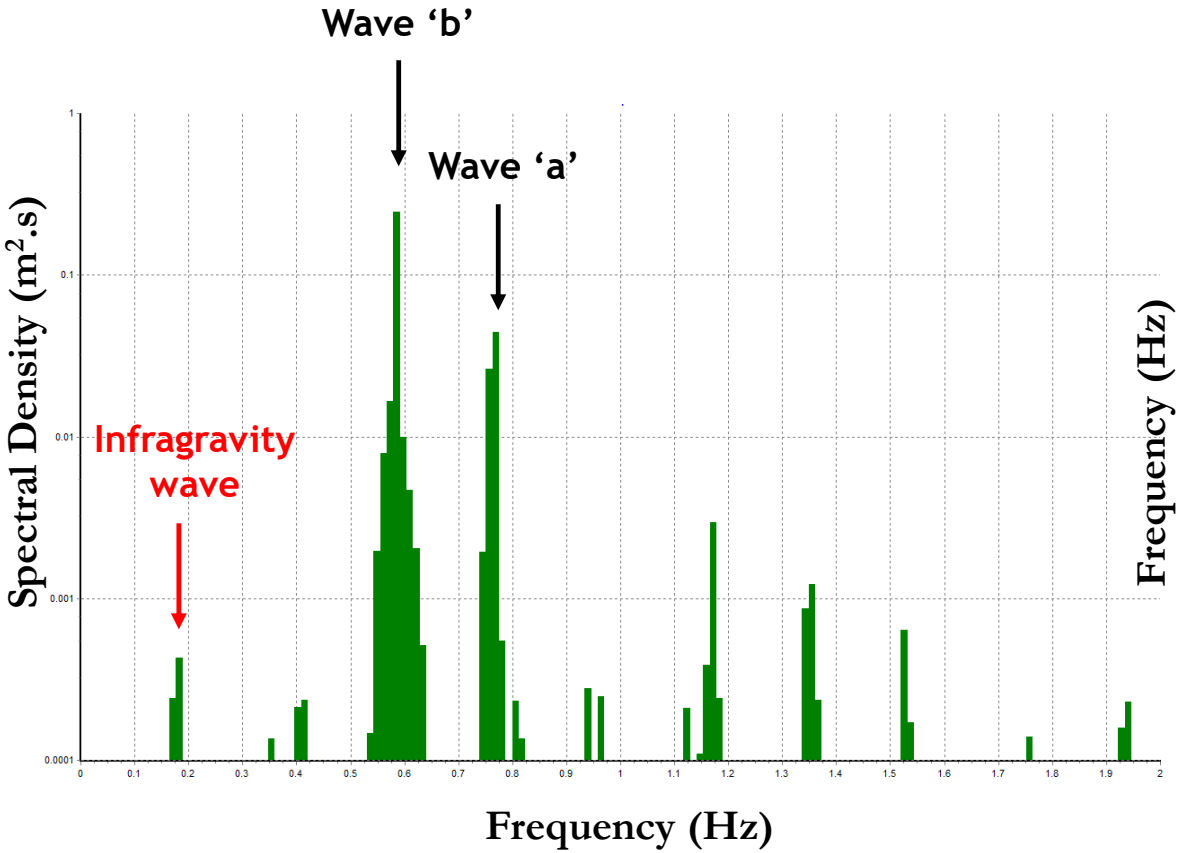
Real (data) dimension

Mathematical (noise) dimension

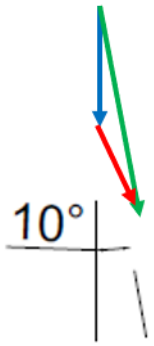
Results

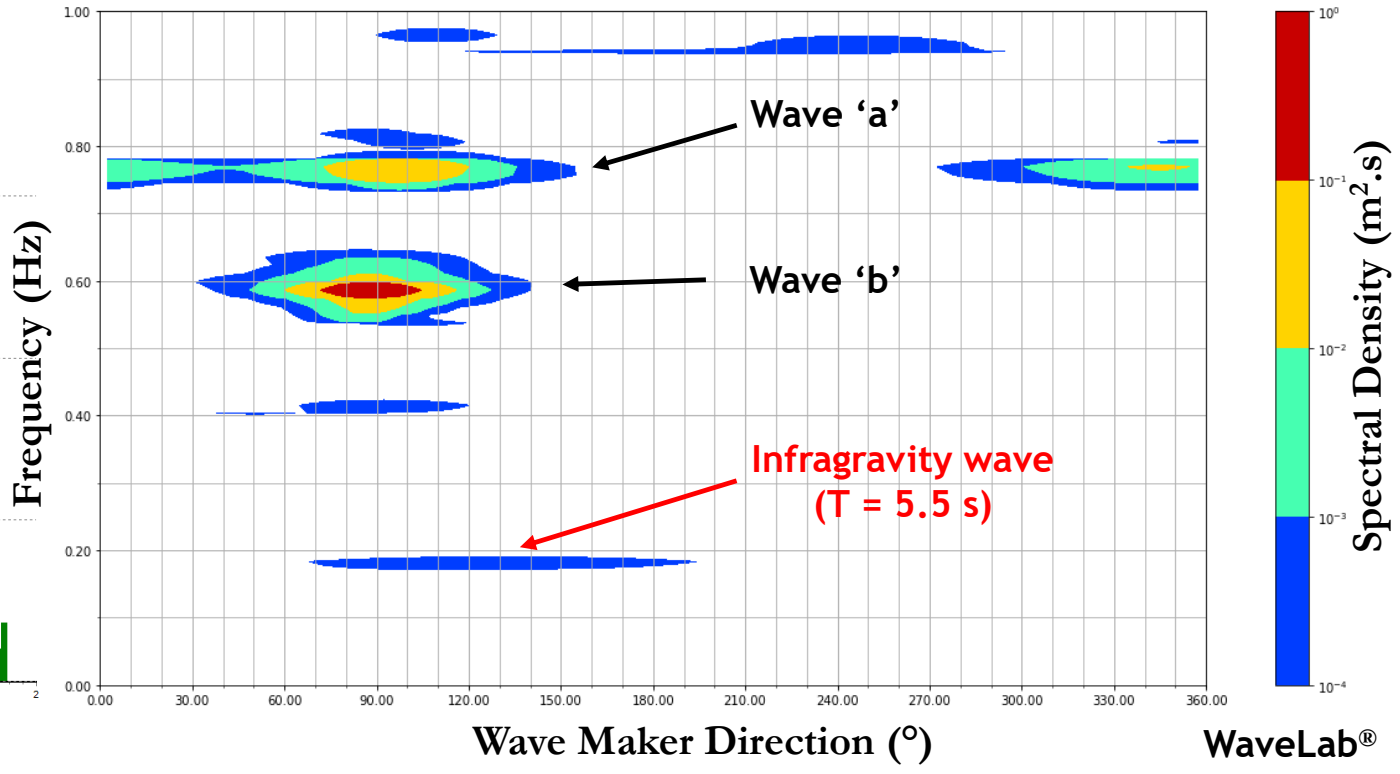
- **Test 1** (h = 0.75 m / ADV at 35 cm):
  - Wave ‘a’: H = 0.10 m / T = 1.3 s / D = 10°
  - Wave ‘b’: H = 0.16 m / T = 1.7 s / D = 0°

2D Variance Spectrum



3D Variance Spectrum





WaveLab®

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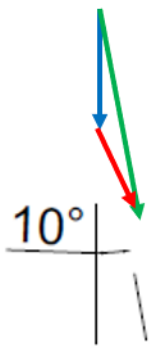
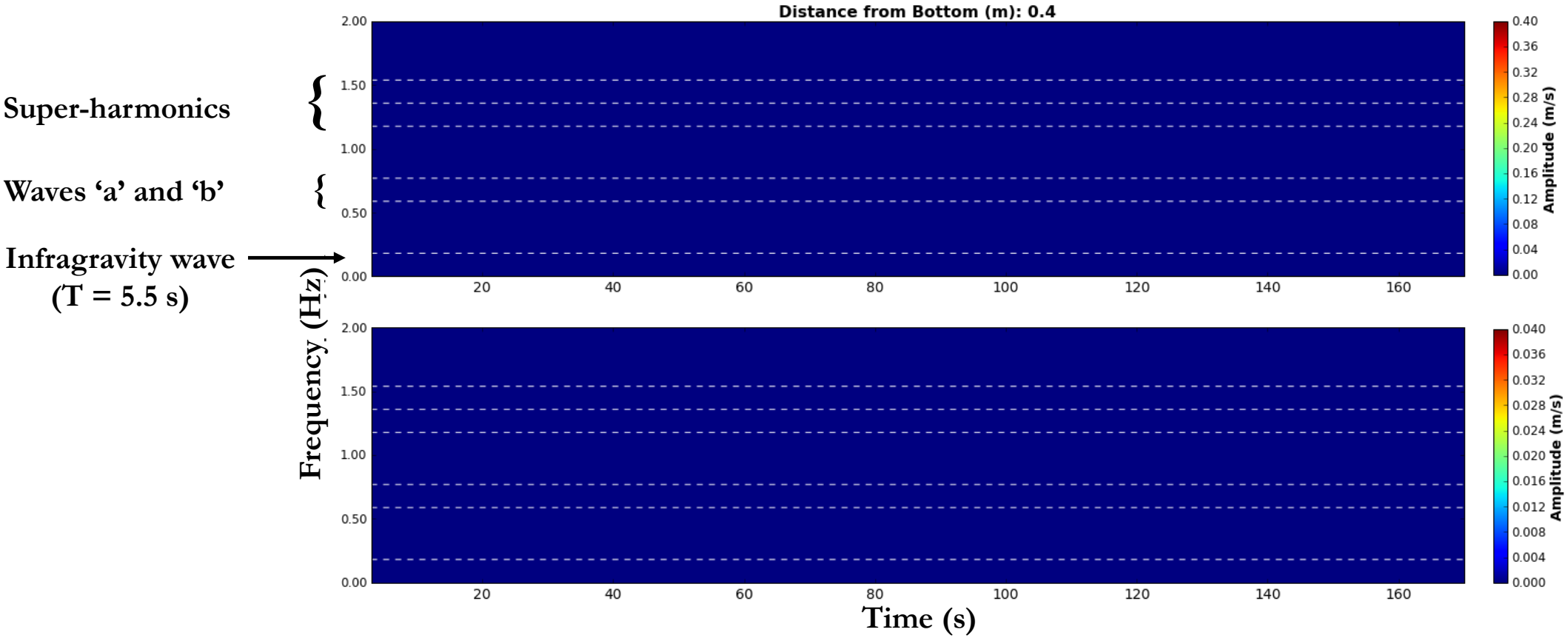


Horizontal U Velocity



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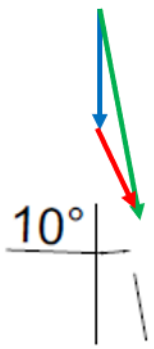

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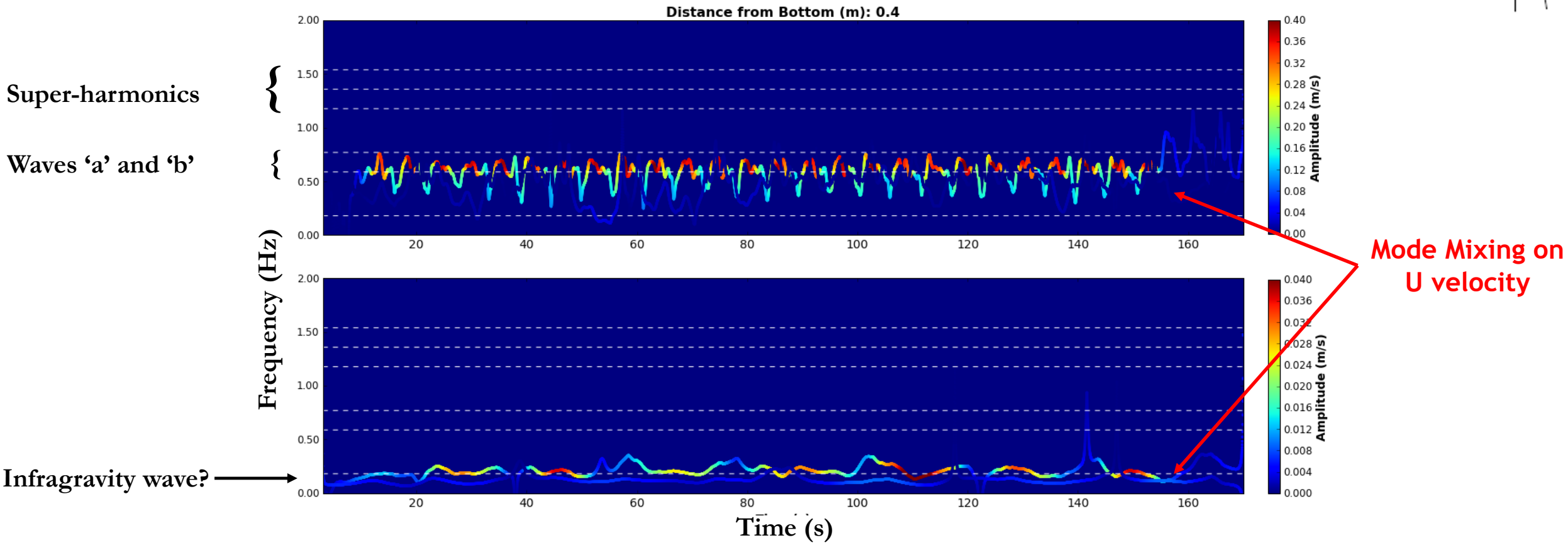

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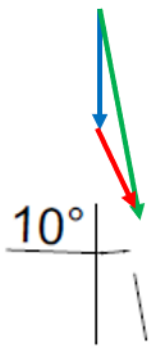

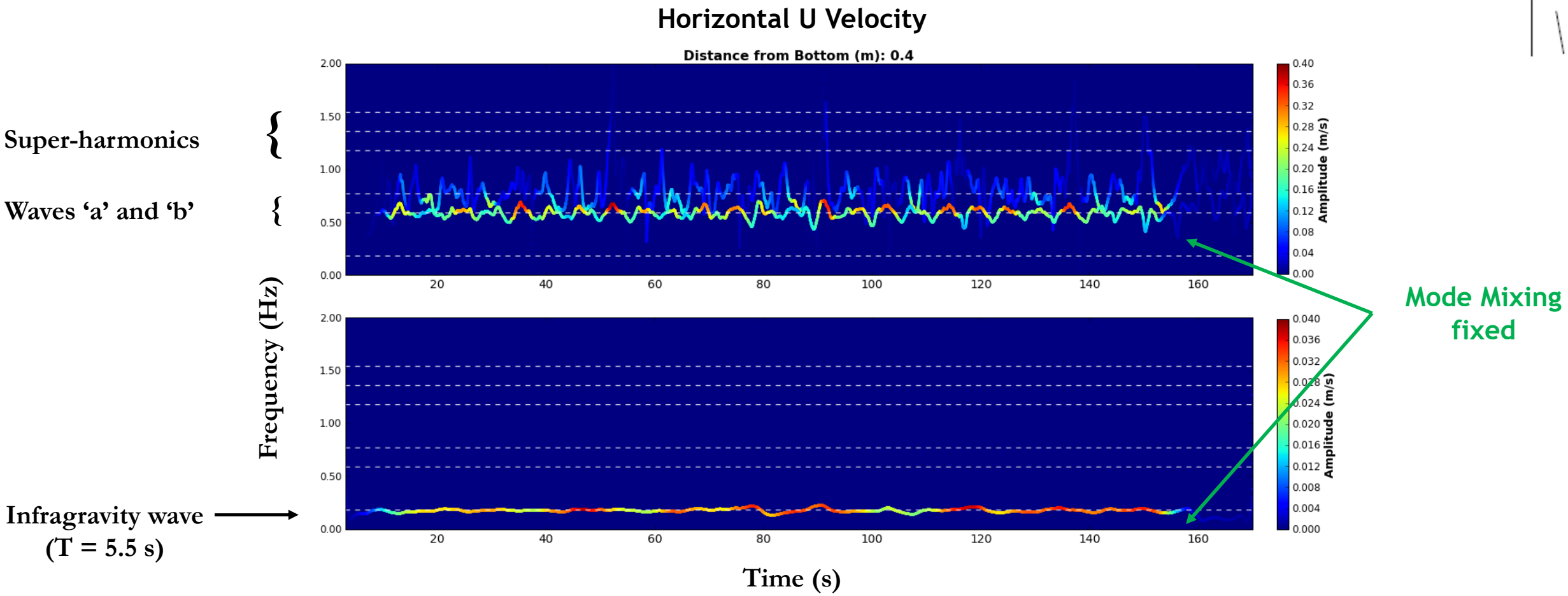

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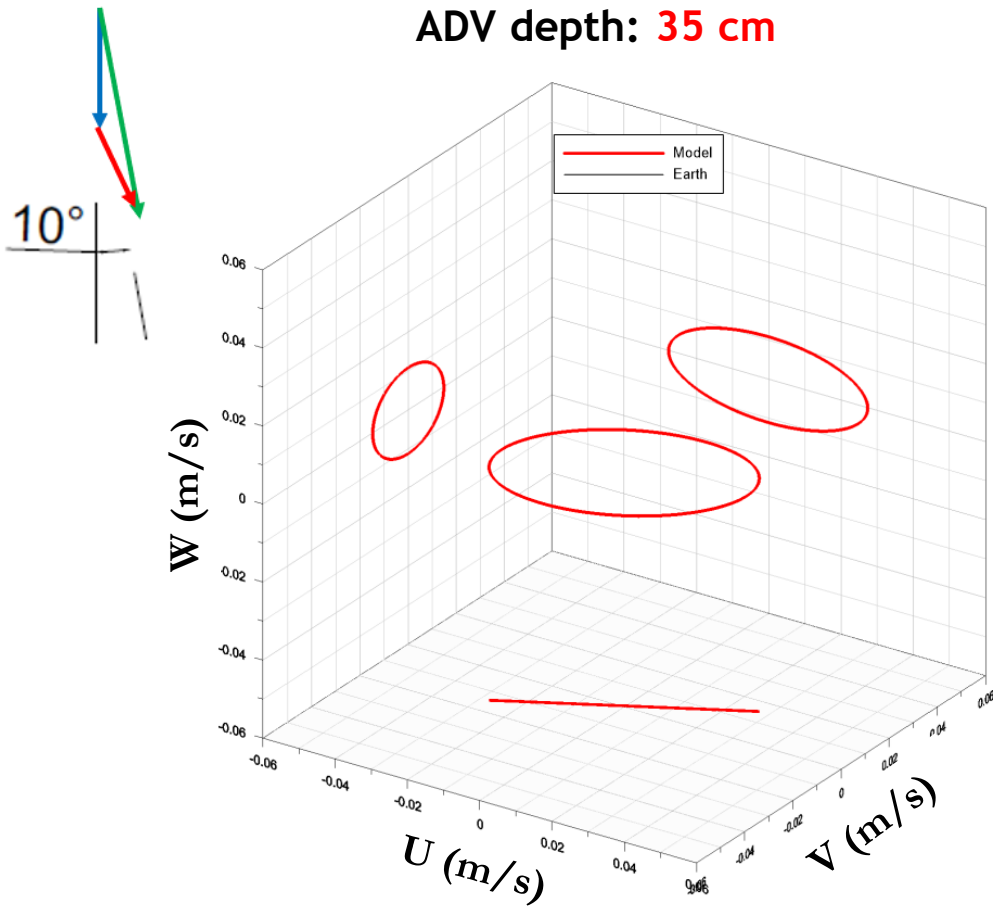

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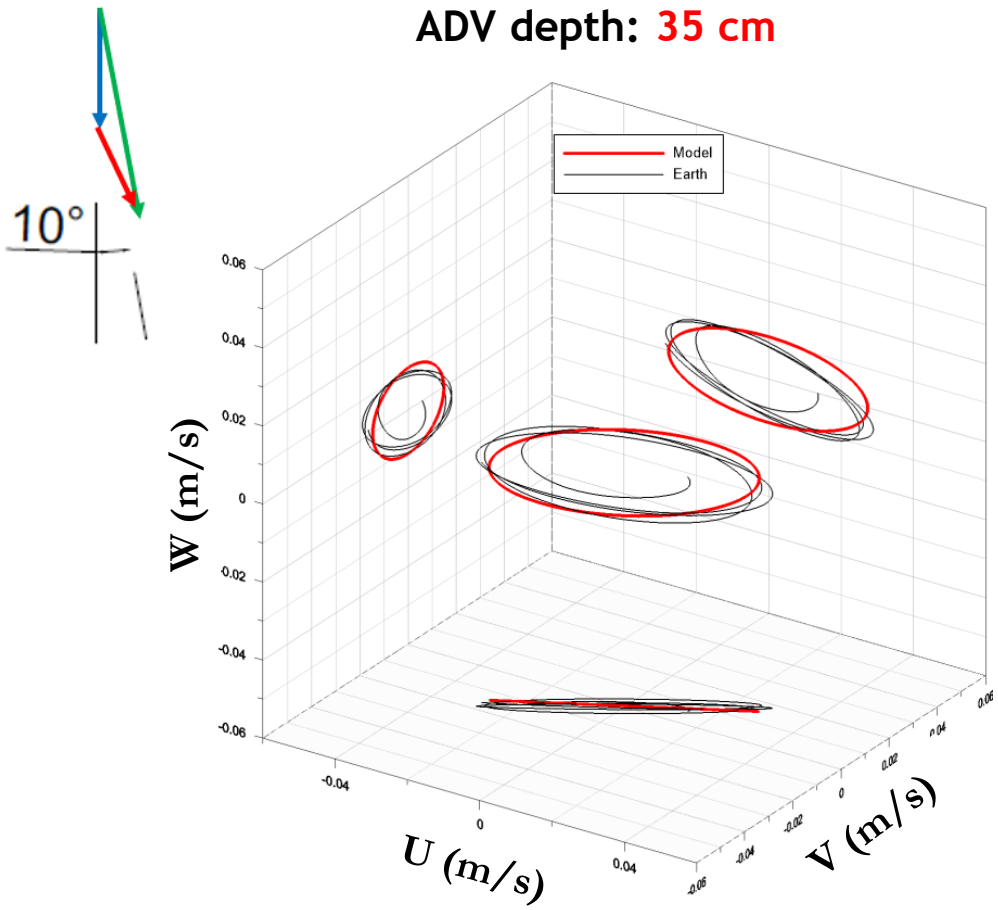

Results

- **Test 1 x Test 2** (h = 0.75 m):
  - Wave ‘a’: H = 0.10 m / T = 1.3 s / D = 10°
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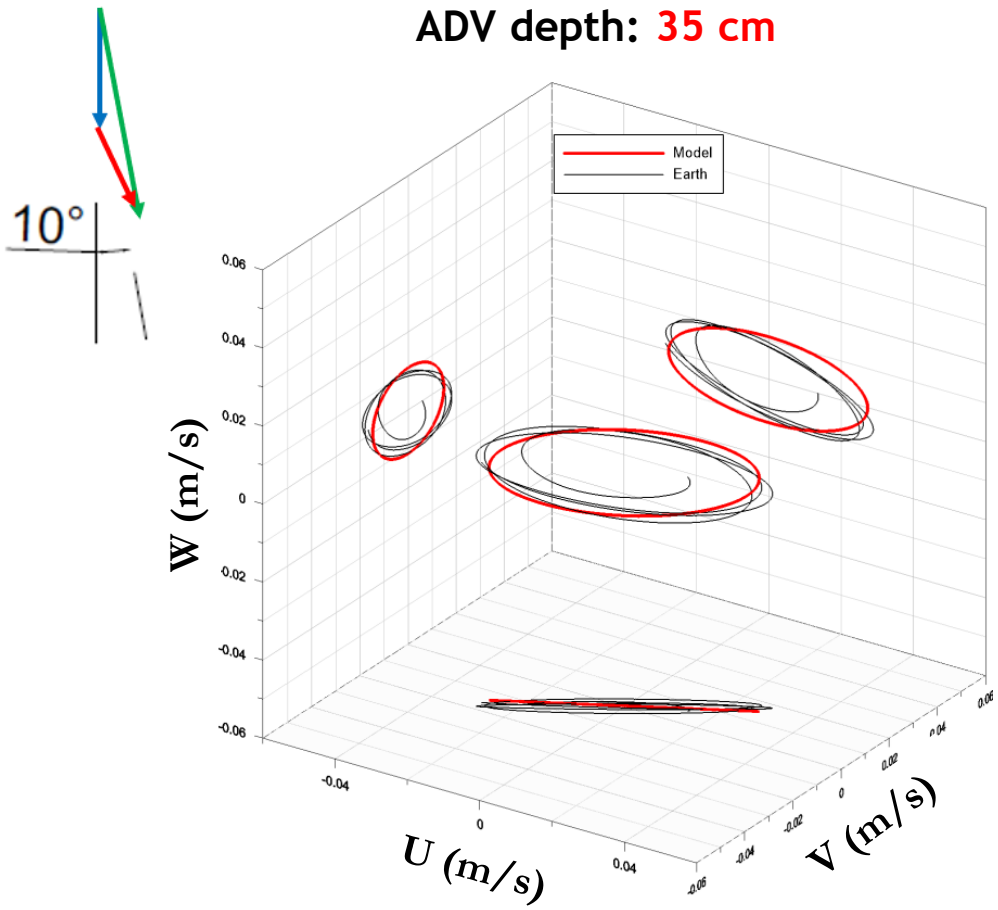
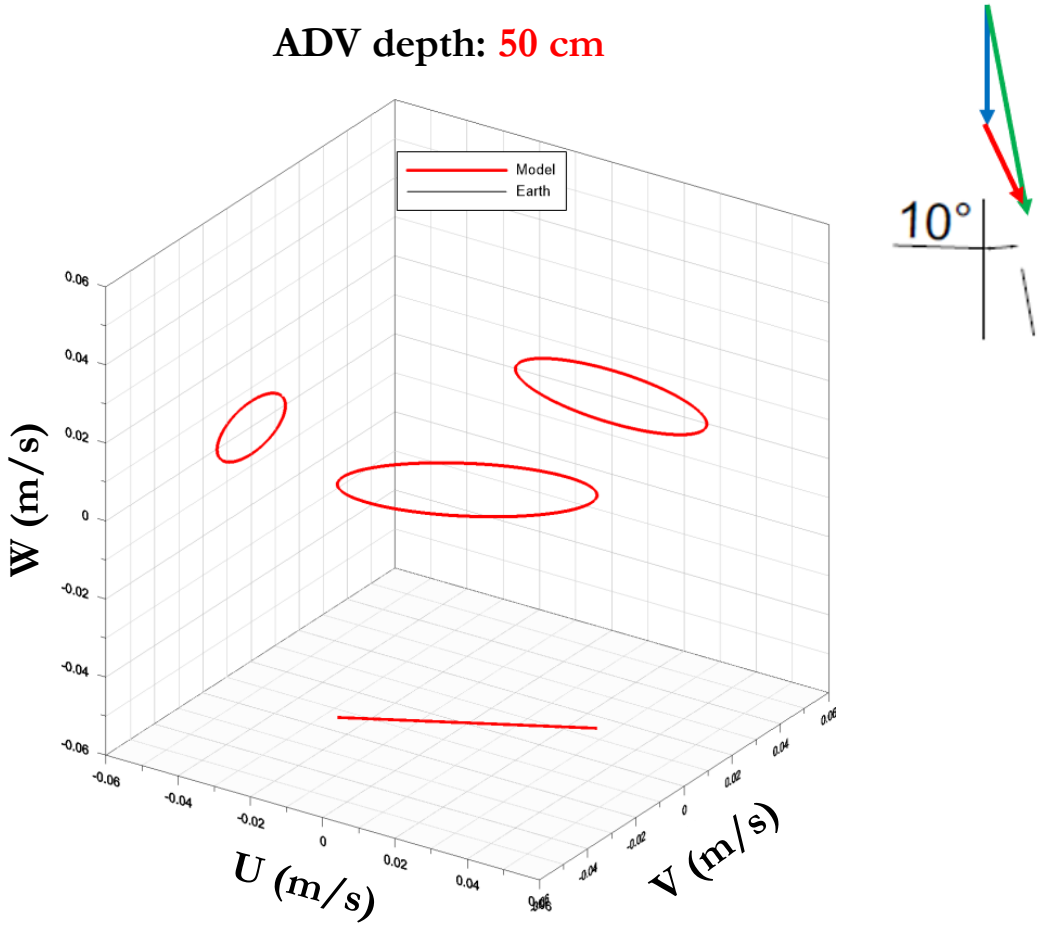
ADV depth: 35 cm



ADV depth: 50 cm



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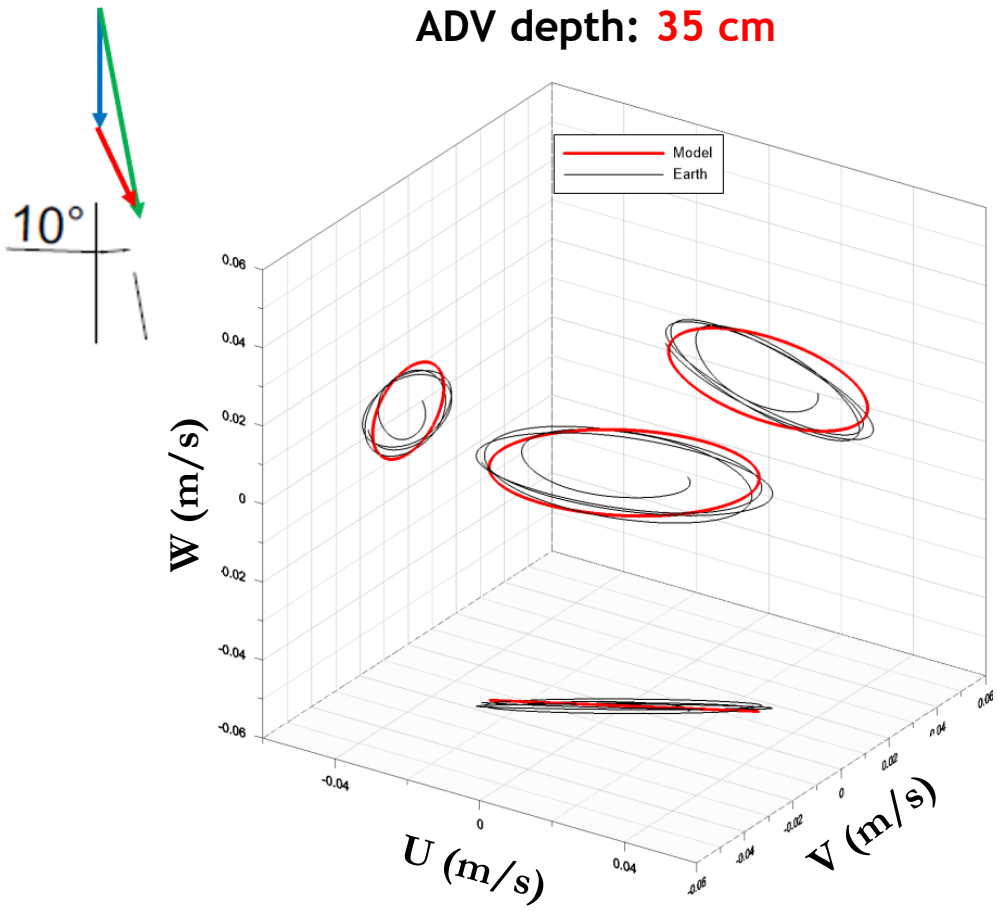

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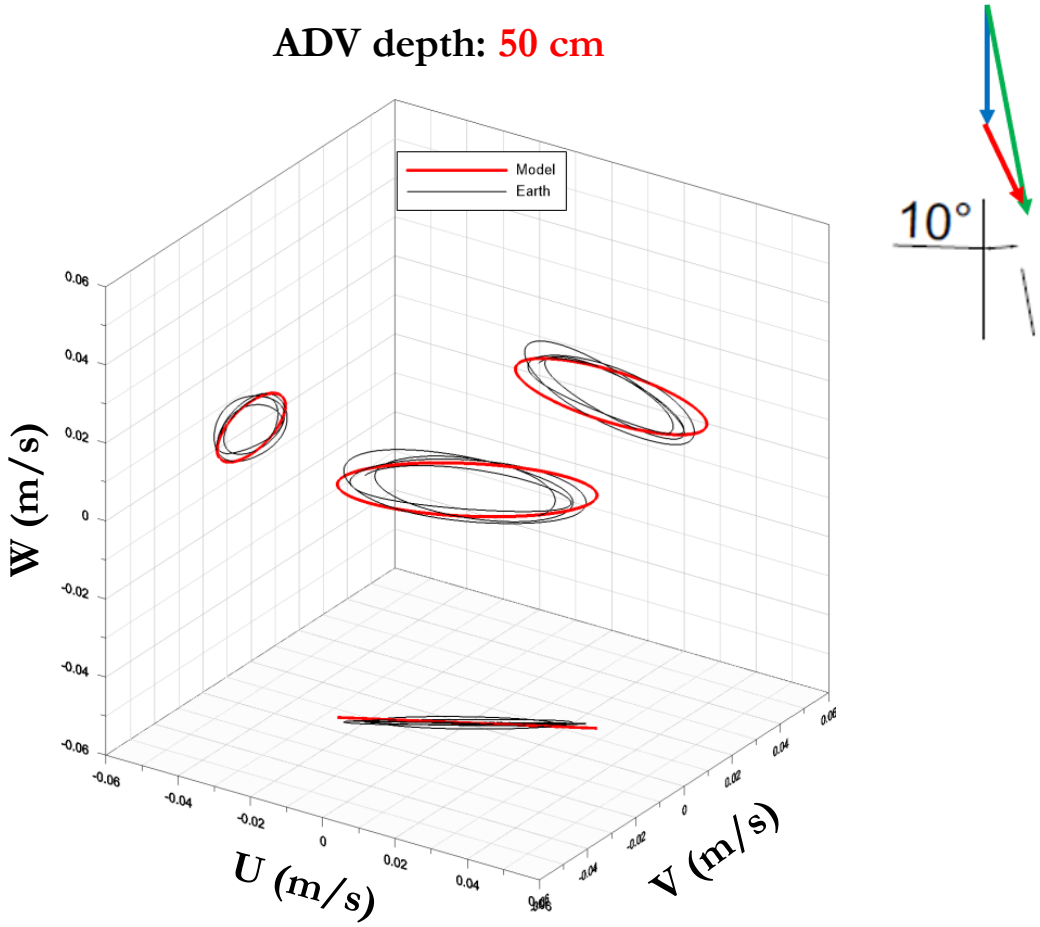

Results

- **Test 1 x Test 3** (h = 0.75 m):
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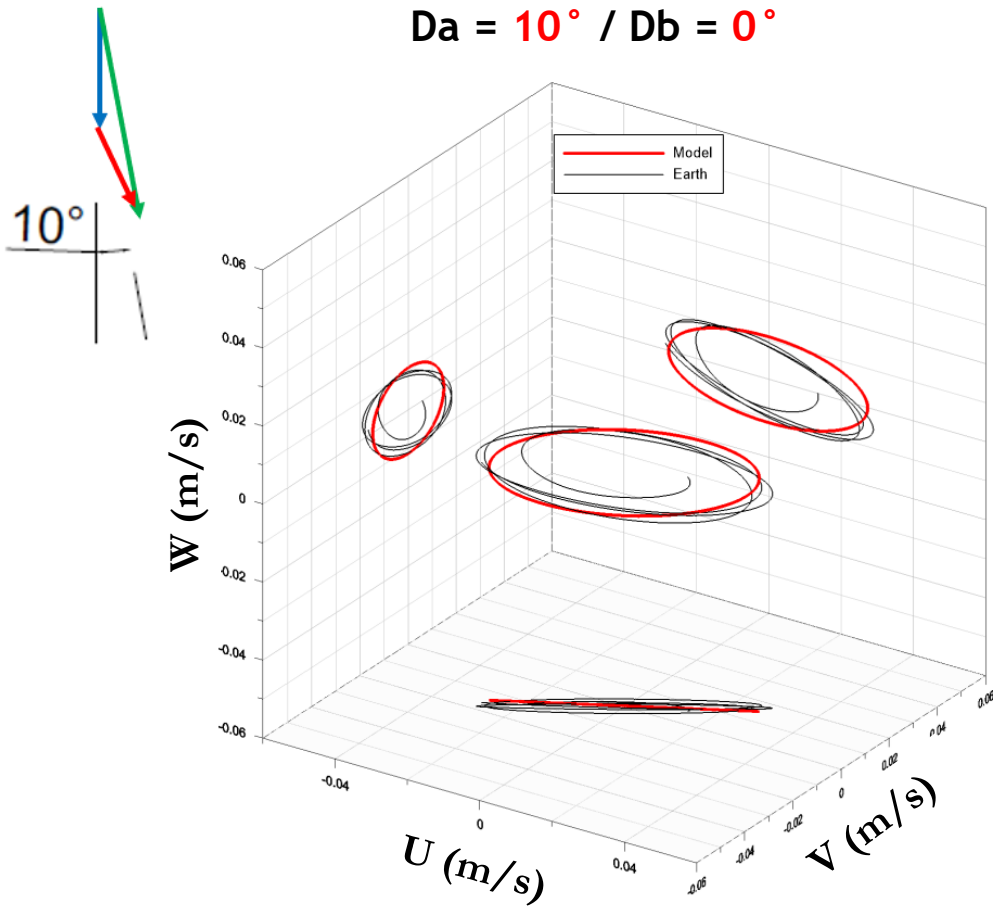
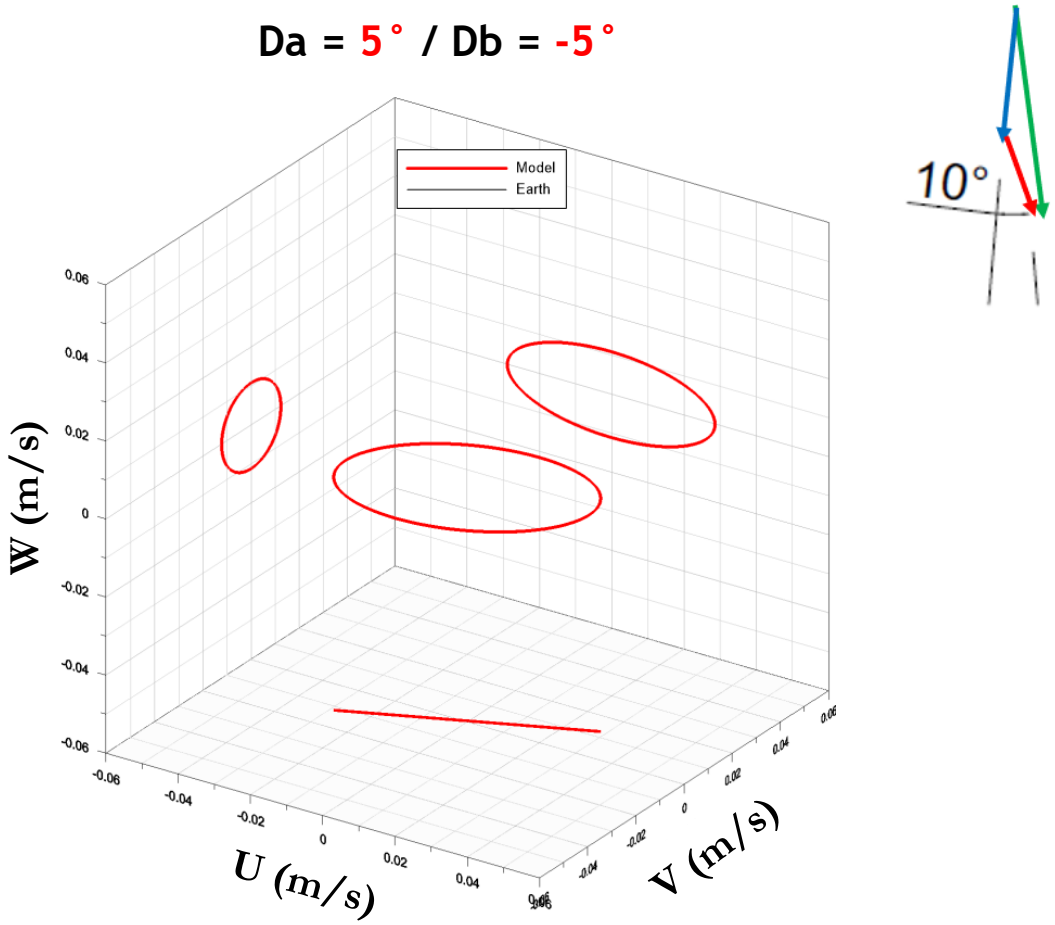
Da = 10° / Db = 0°



Da = 5° / Db = -5°



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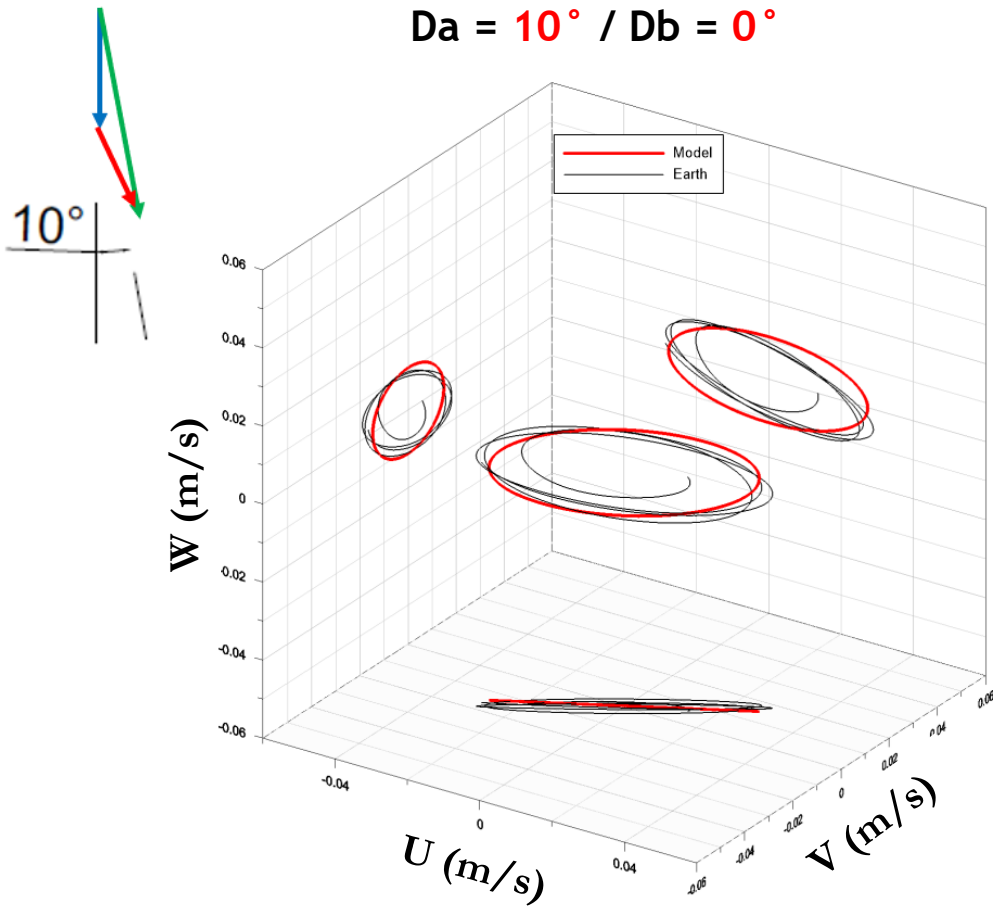

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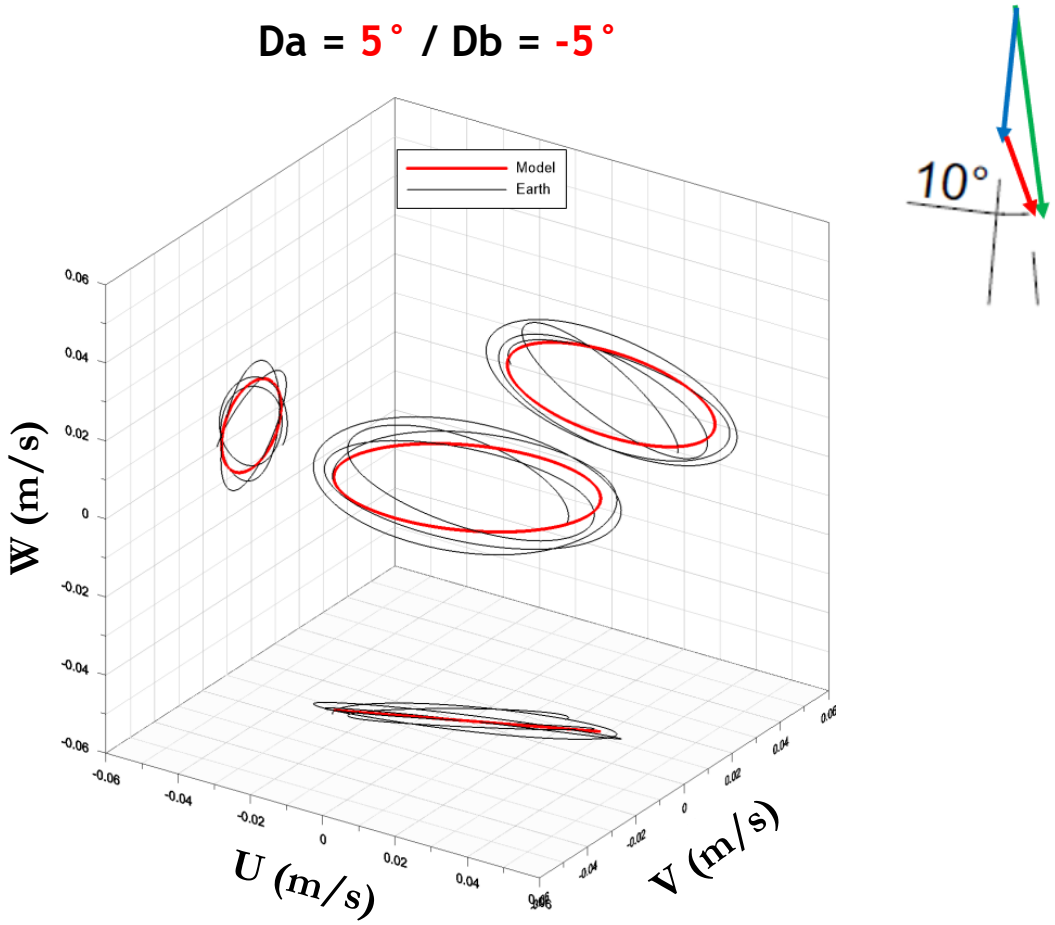
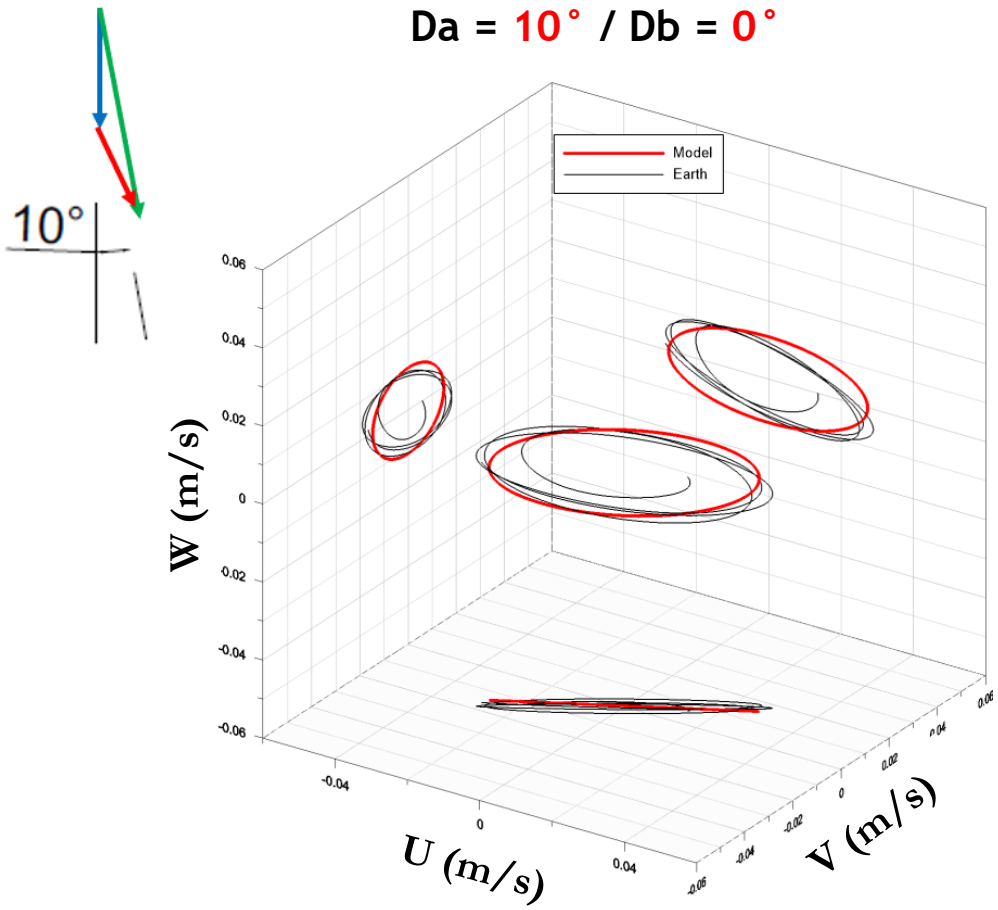


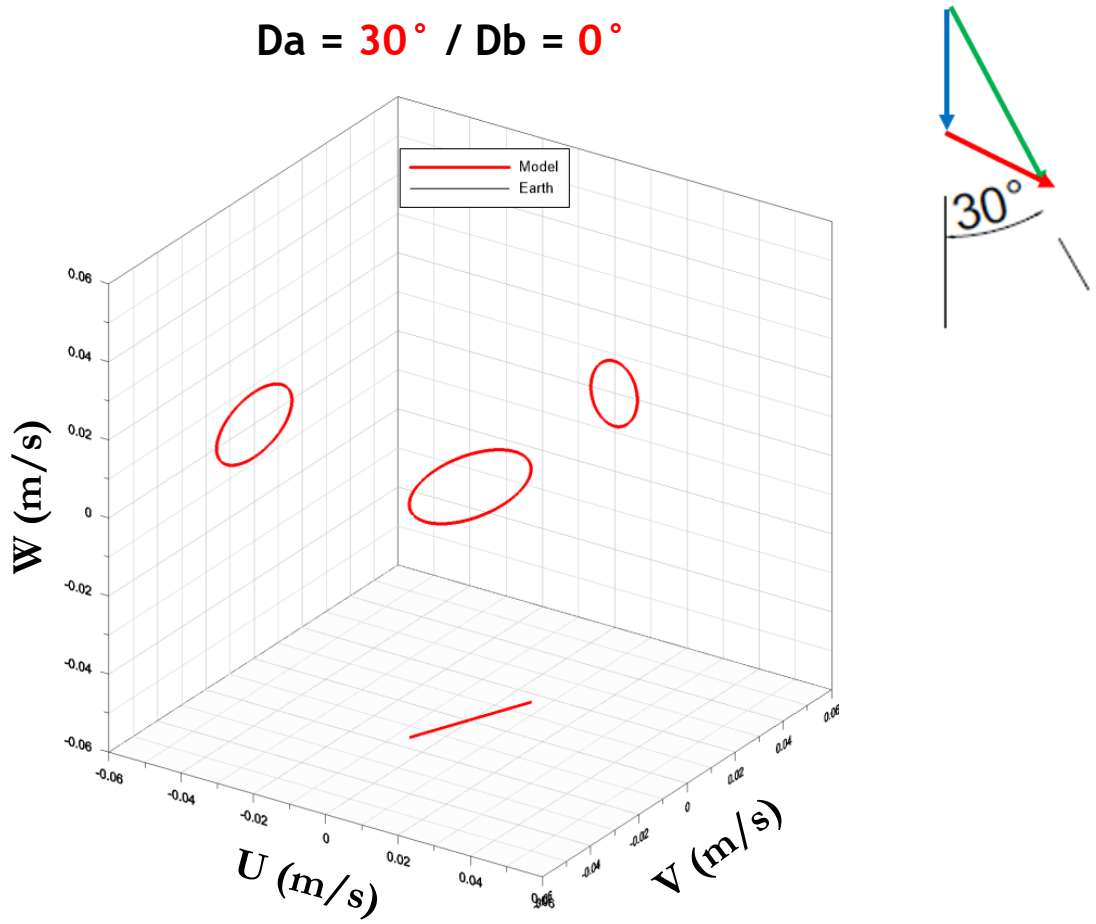
Results

- **Test 1 x Test 4** (h = 0.75 m):
  - Wave ‘a’: H = 0.10 m / T = 1.3 s
  - Wave ‘b’: H = 0.16 m / T = 1.7 s

Da = 10° / Db = 0°



Da = 30° / Db = 0°



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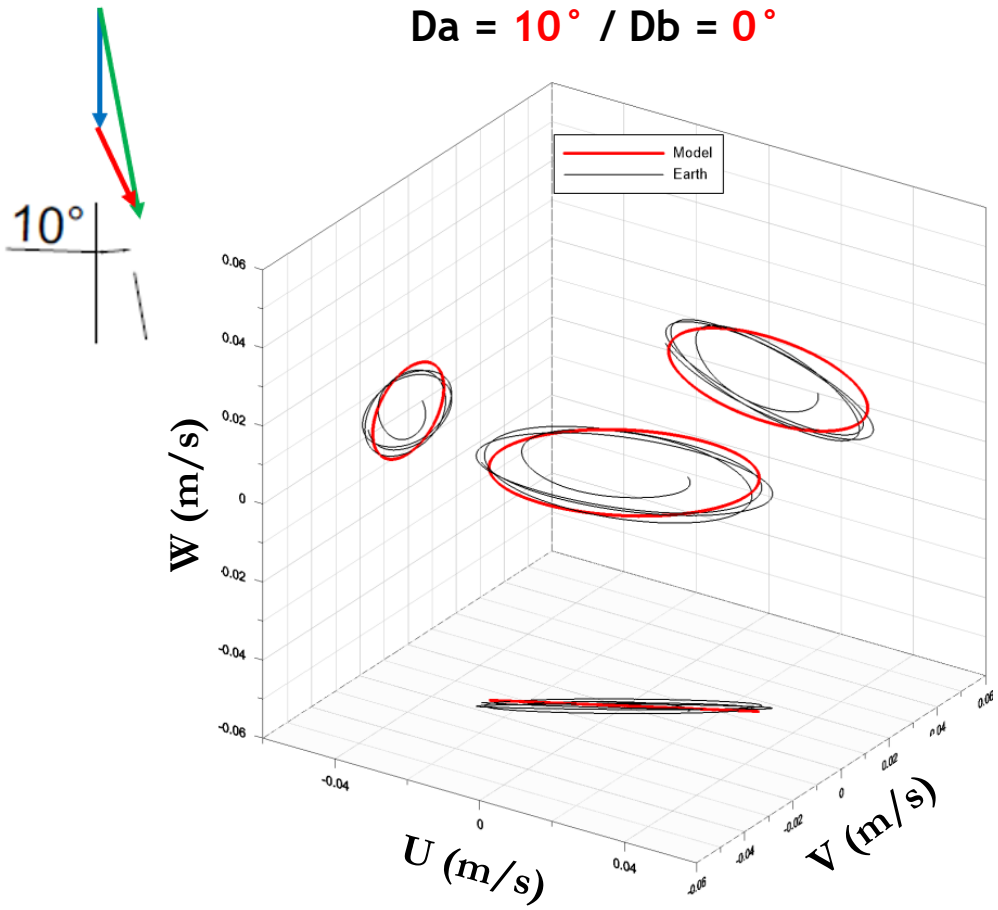
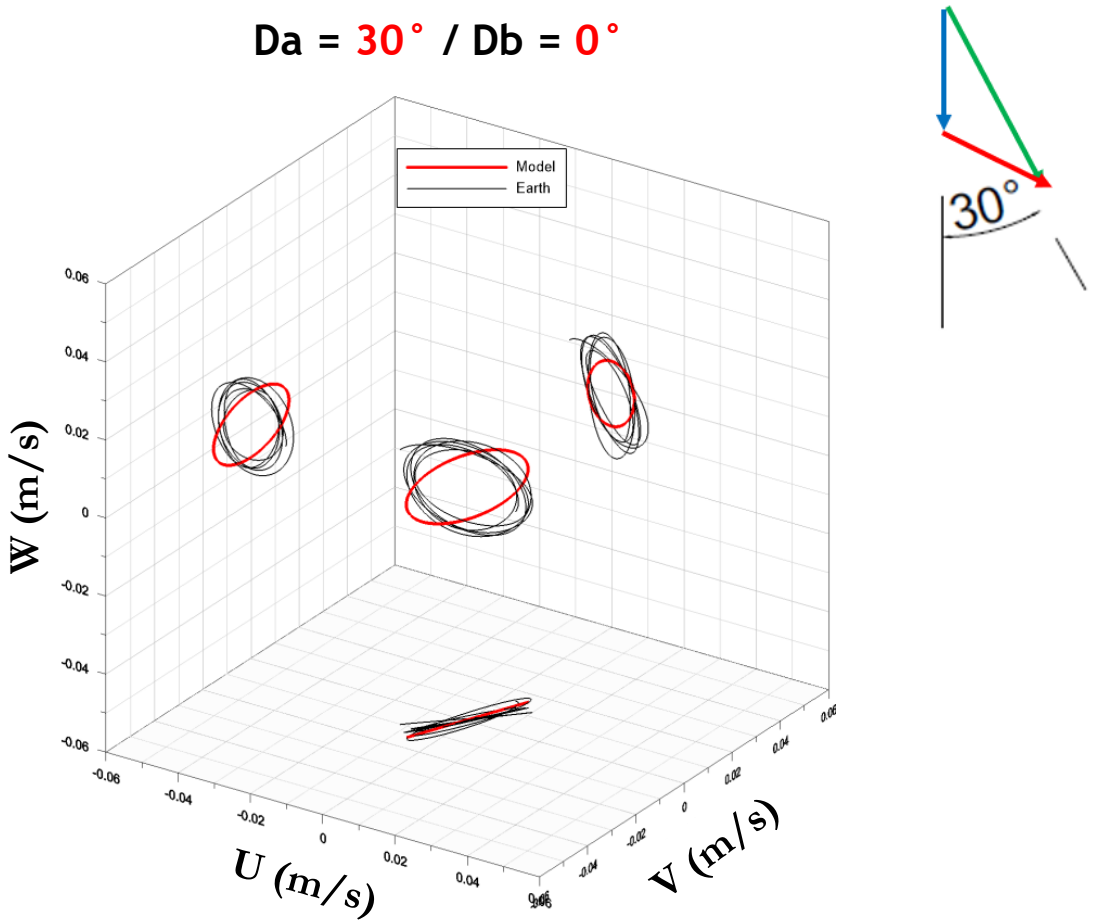
Da = 10° / Db = 0°



Da = 30° / Db = 0°



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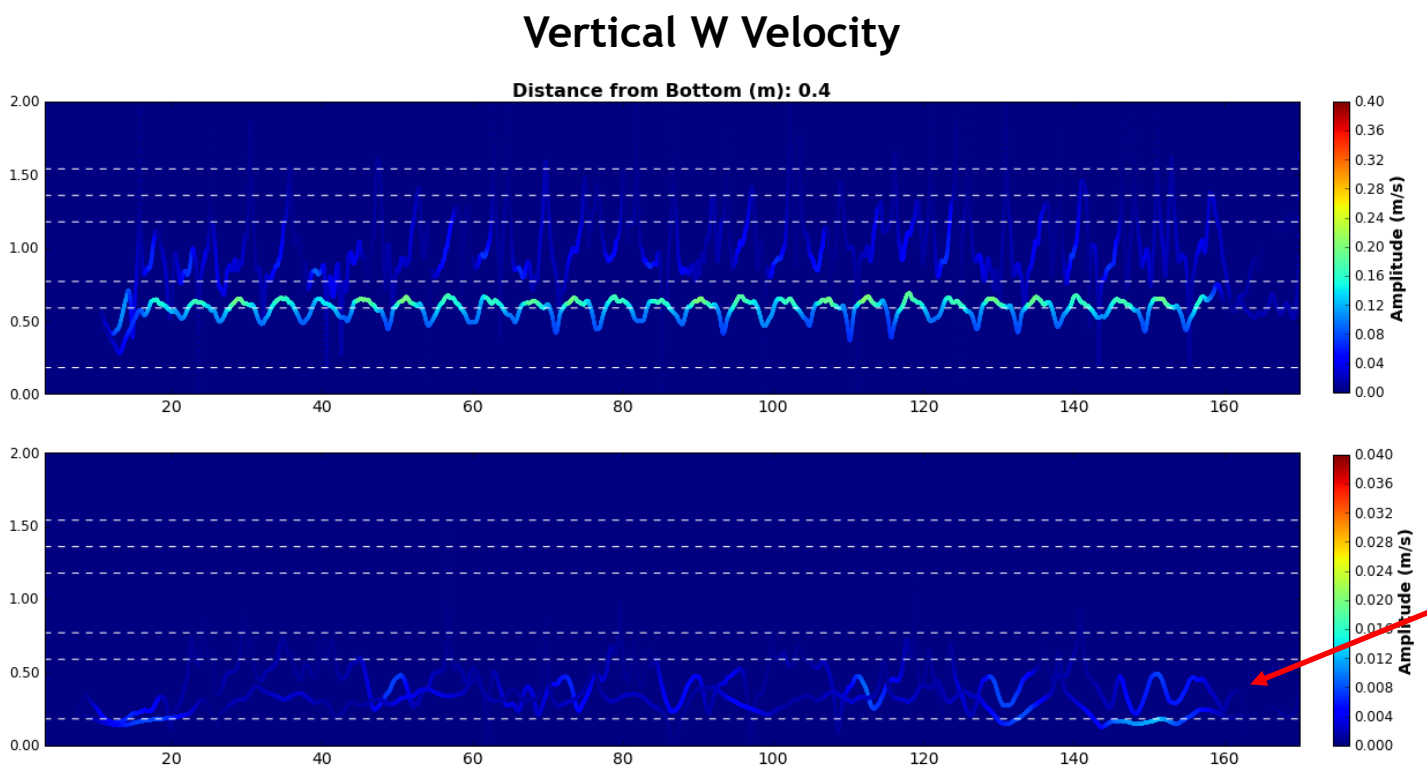
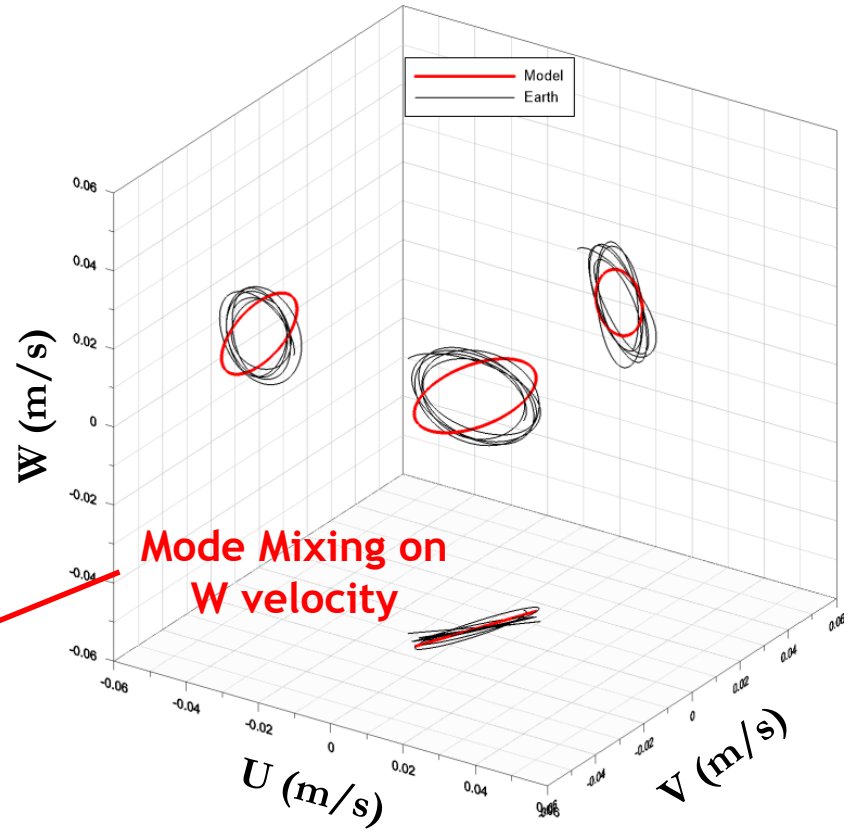
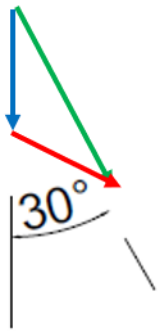
Da = 30° / Db = 0°



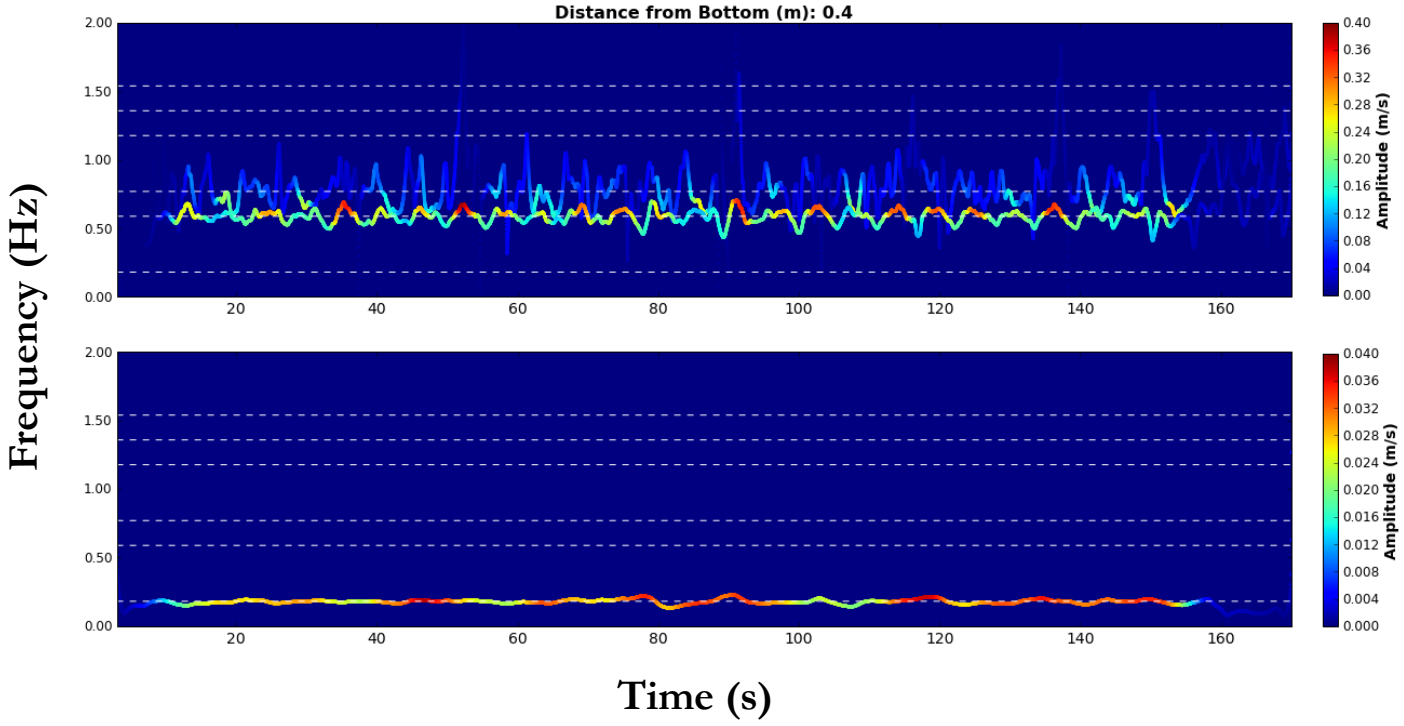




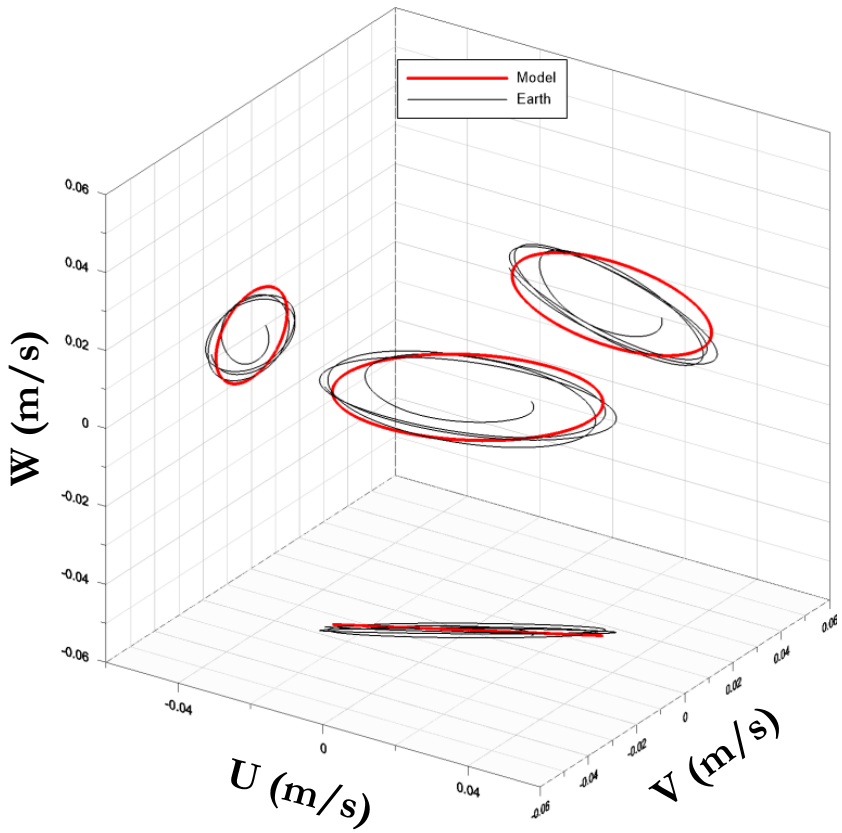
Conclusions

- Infragravity wave detection with ADV:
  - HHT

Frequency



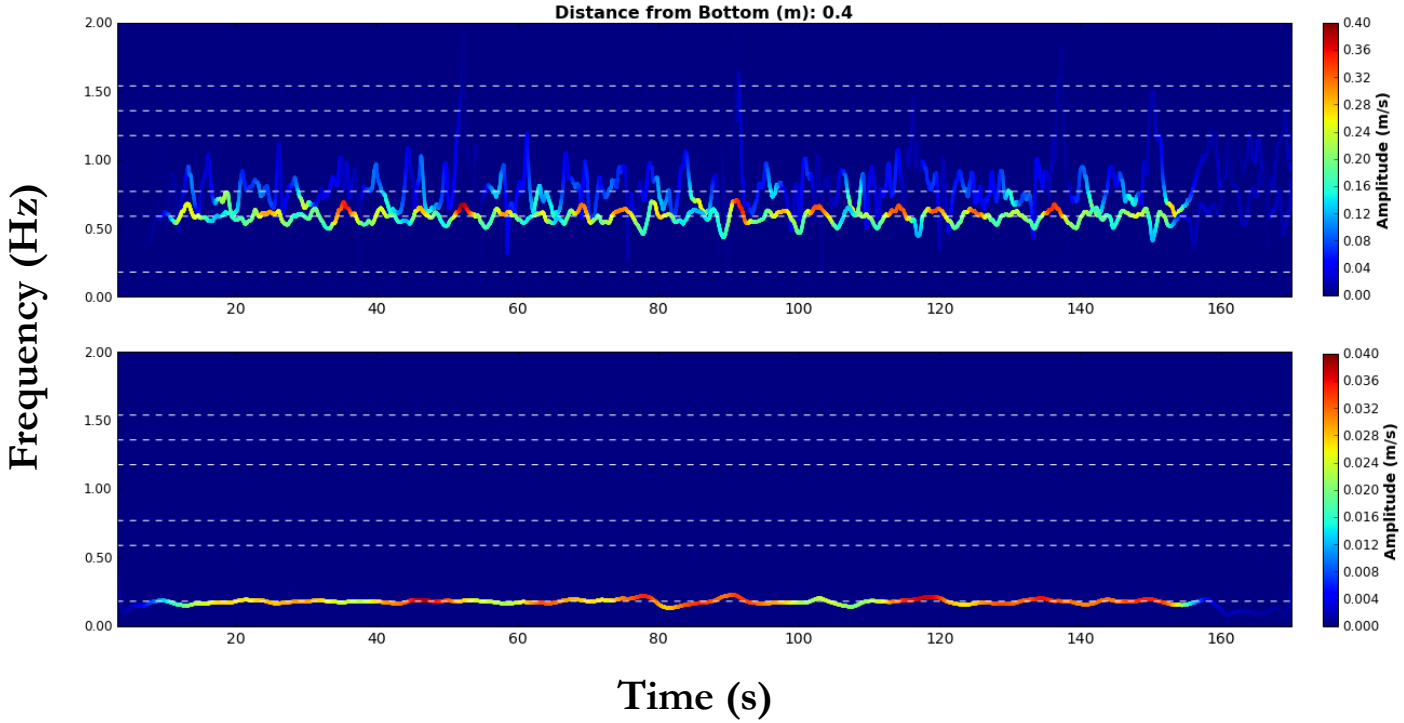
Amplitude and Direction



Conclusions

- Infragravity wave detection with ADV:
  - HHT
  - MEMD

Array of ADVs



Acknowledgments

CAPES

Ludwig-Franzius-Institute
for Hydraulic, Estuarine and
Coastal Engineering

Experiments

Test	h (m)	d/h (%)	Ha (cm)	Hb (cm)	T (s)	D (°)
T1	0.60	58	13	13	Combination of 3 different periods (1.1 – 3.0)	Combination of 3 different angle deltas (0, 10, 30)
T2	0.60	58	10	16		
T3	0.75	47	13	13		
T4	0.75	47	10	16		

- 2 different water depths;

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- 2 different water depths;
- 2 different combinations of have heights: Ha + Hb = 26 cm;
- 3 different periods/group: 1.2, 1.5 and 2.3s, for example;

T1		
Combinations	Ta (s)	Tb (s)
1A	1.2	1.2
1B	1.2	1.5
1C	1.2	2.3
1D	1.5	1.5
1E	1.5	2.3
1F	2.3	2.3

Experiments

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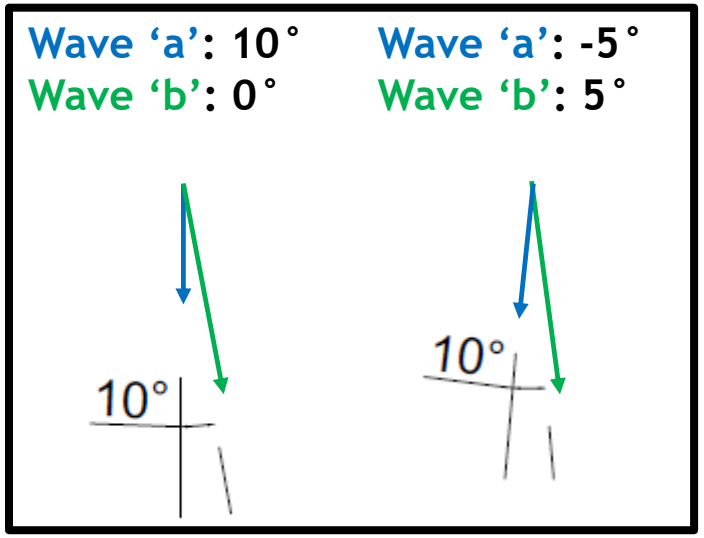
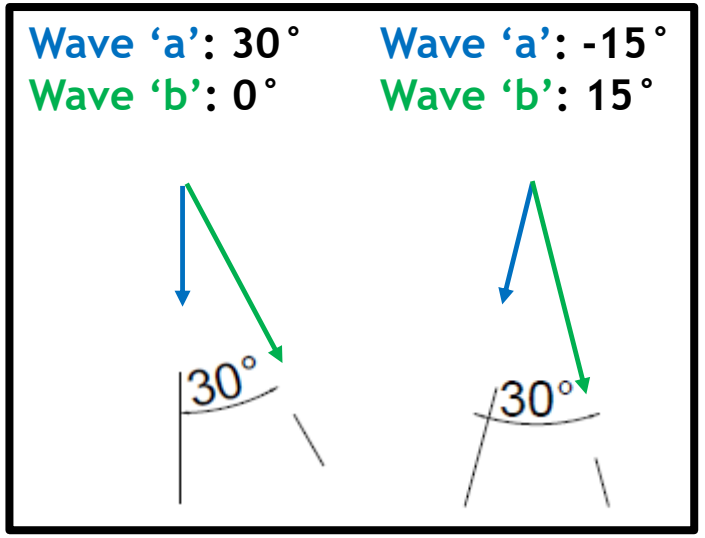
- 3 different angle deltas: 0°, 10° and 30°.

T1			
Combinations	Da (°)	Db (°)	ΔD (°)
1A1	0	0	0
1A2	10	0	10
1A3	30	0	30
1A4	5	-5	10
1A5	15	-15	30





Experiments

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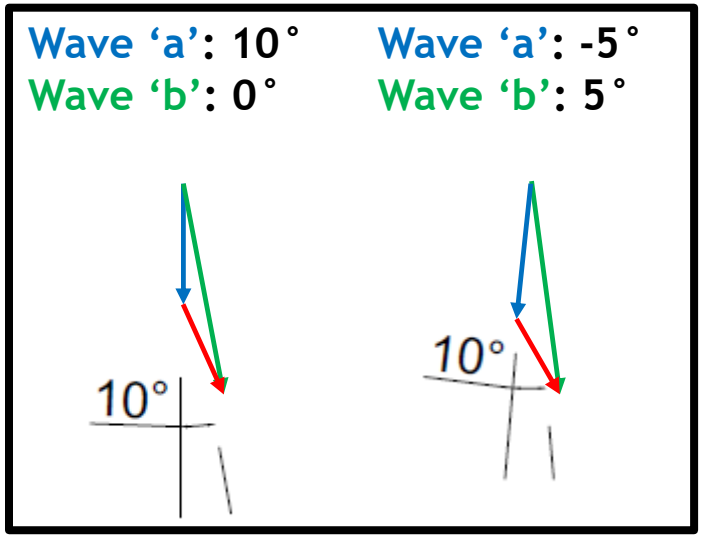

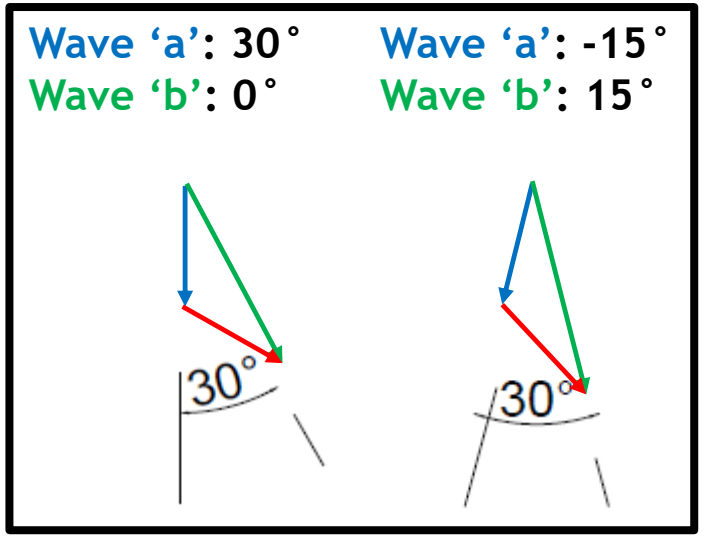

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Extra Tests						
T2*	0.60	58	5	11		
T4*	0.75	67	10	16		
T5*	Bimodal Spectra					

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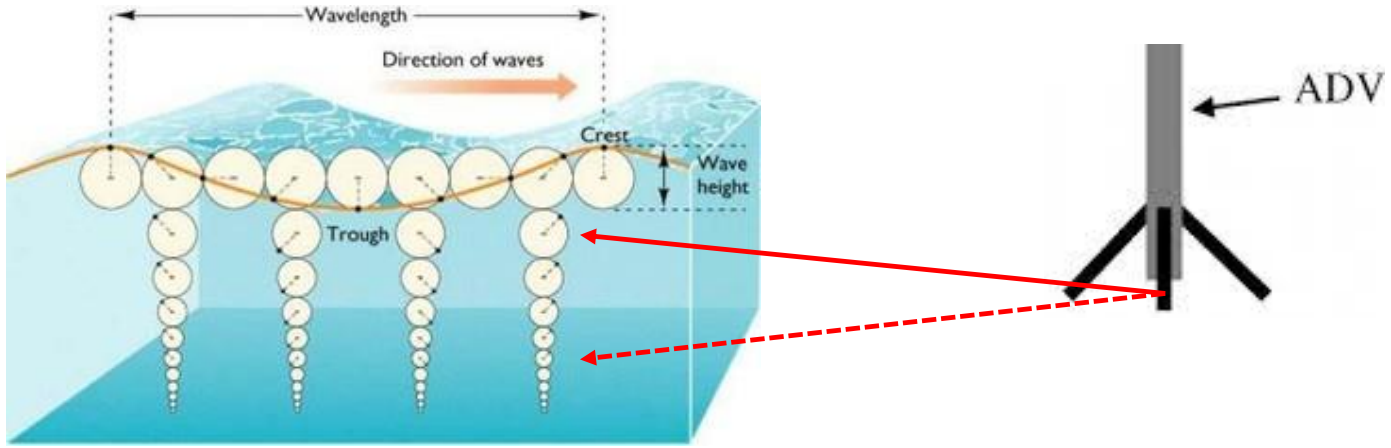

Experiments

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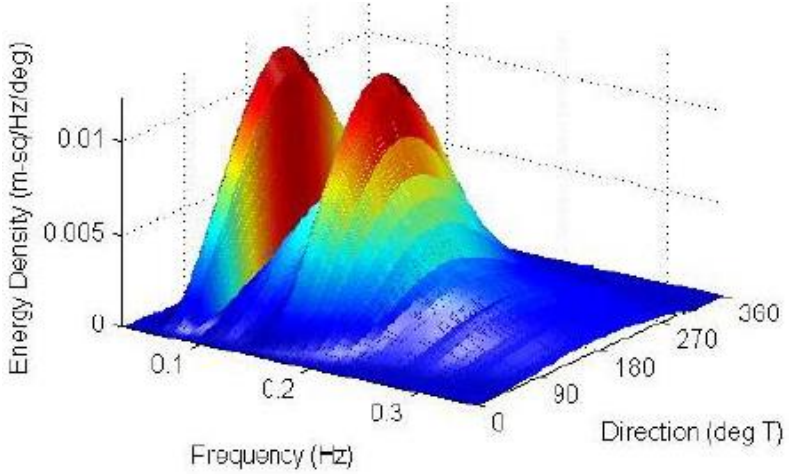
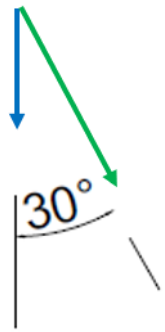
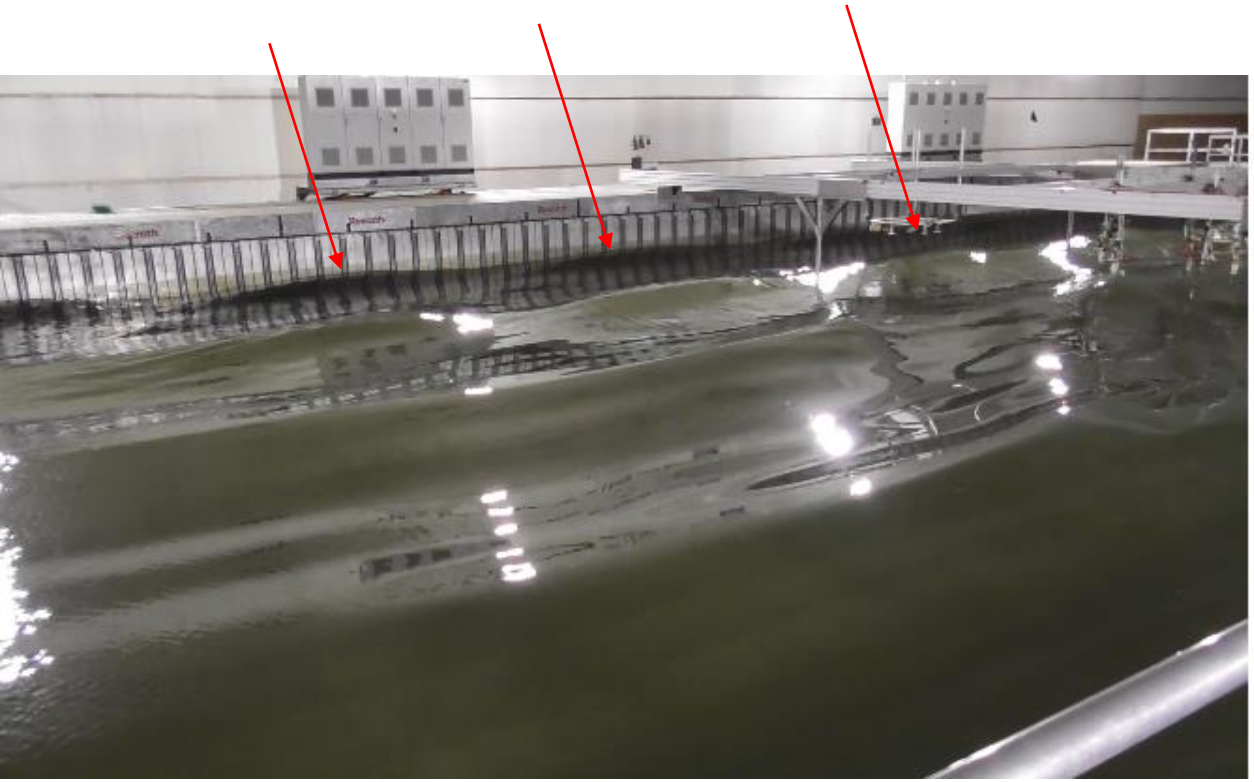


Experiments

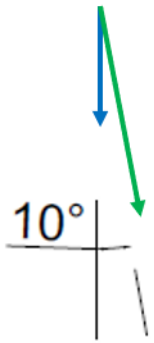
- **Test 4 (h = 0.75 m):**
  - Wave ‘a’: H = 0.10 m / T = 1.3 s / D = 30°
  - Wave ‘b’: H = 0.16 m / T = 1.7 s / D = 0°





Experiments

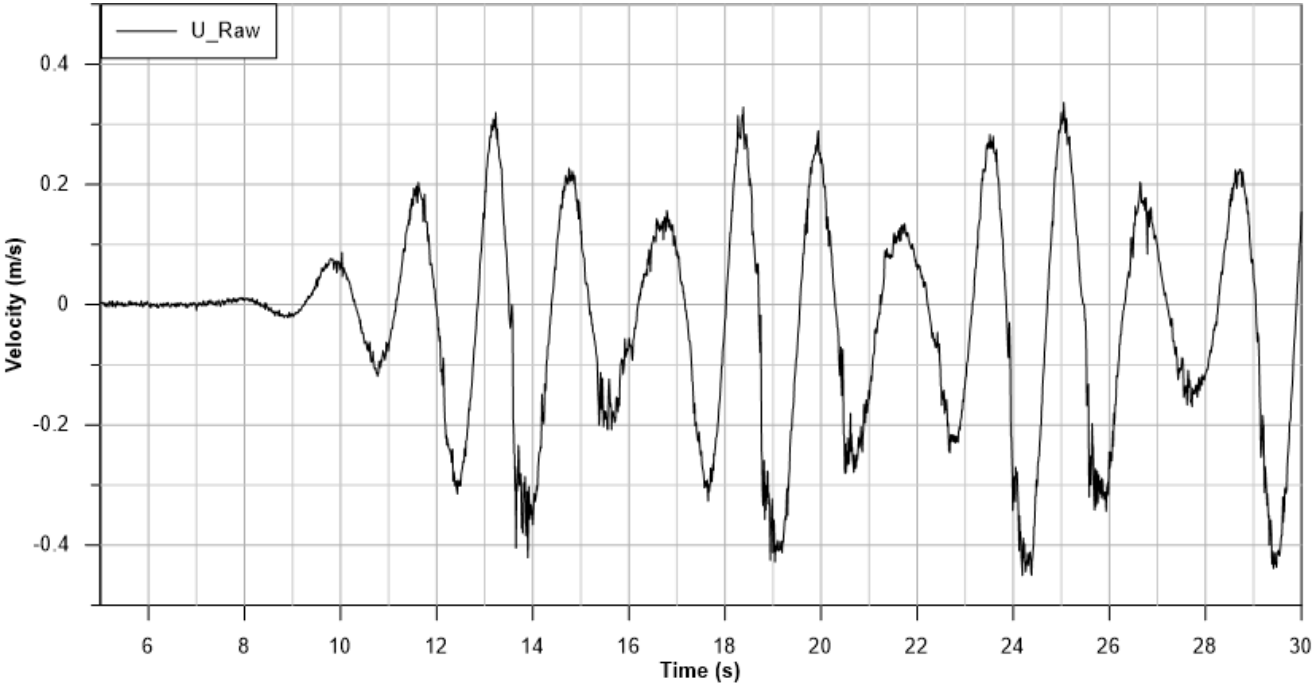
- **Test 1 (h = 0.75 m):**
  - Wave ‘a’: H = 0.10 m / T = 1.3 s / D = 10°
  - Wave ‘b’: H = 0.16 m / T = 1.7 s / D = 0°



Methodology

- **Step 1: Data quality:** seeding material (TiO_2 + circular source);

Raw: Horizontal U Velocity



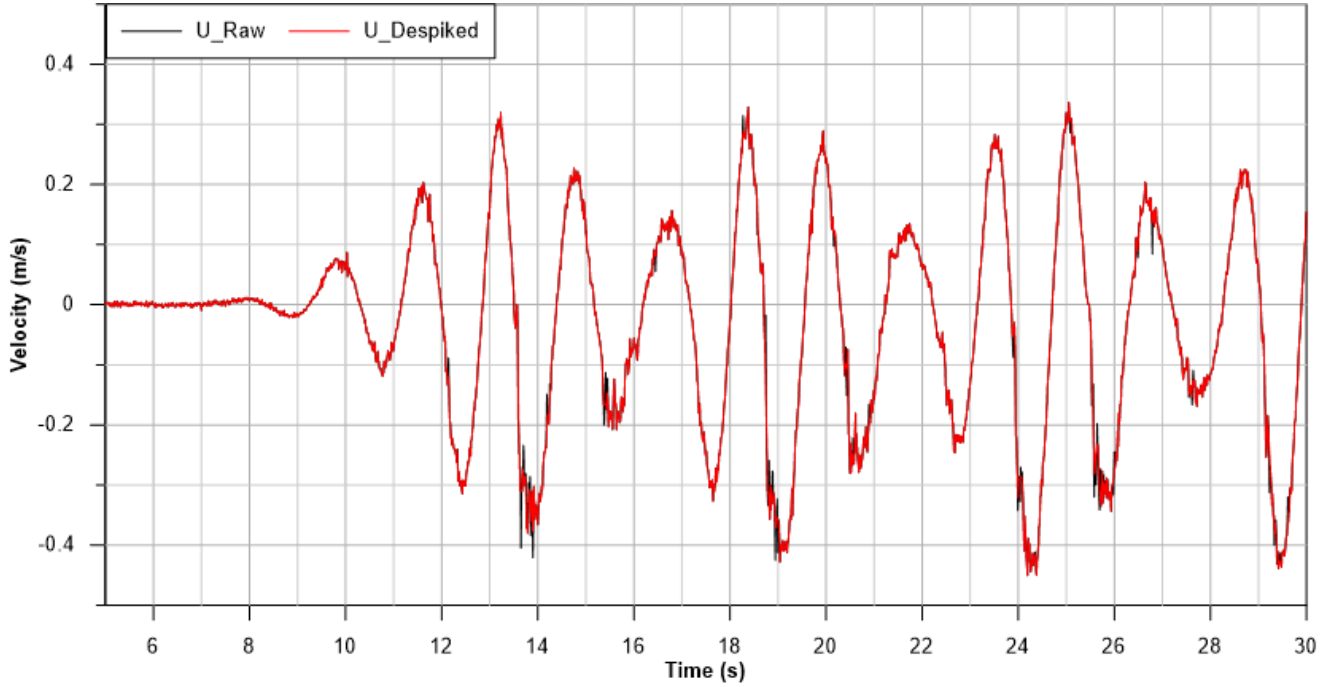
TiO_2

Circular Source

Methodology

- **Step 1: Data quality:** seeding material (TiO_2 + circular source);
- **Step 2: Despike method:** Goring and Nikora (2002);

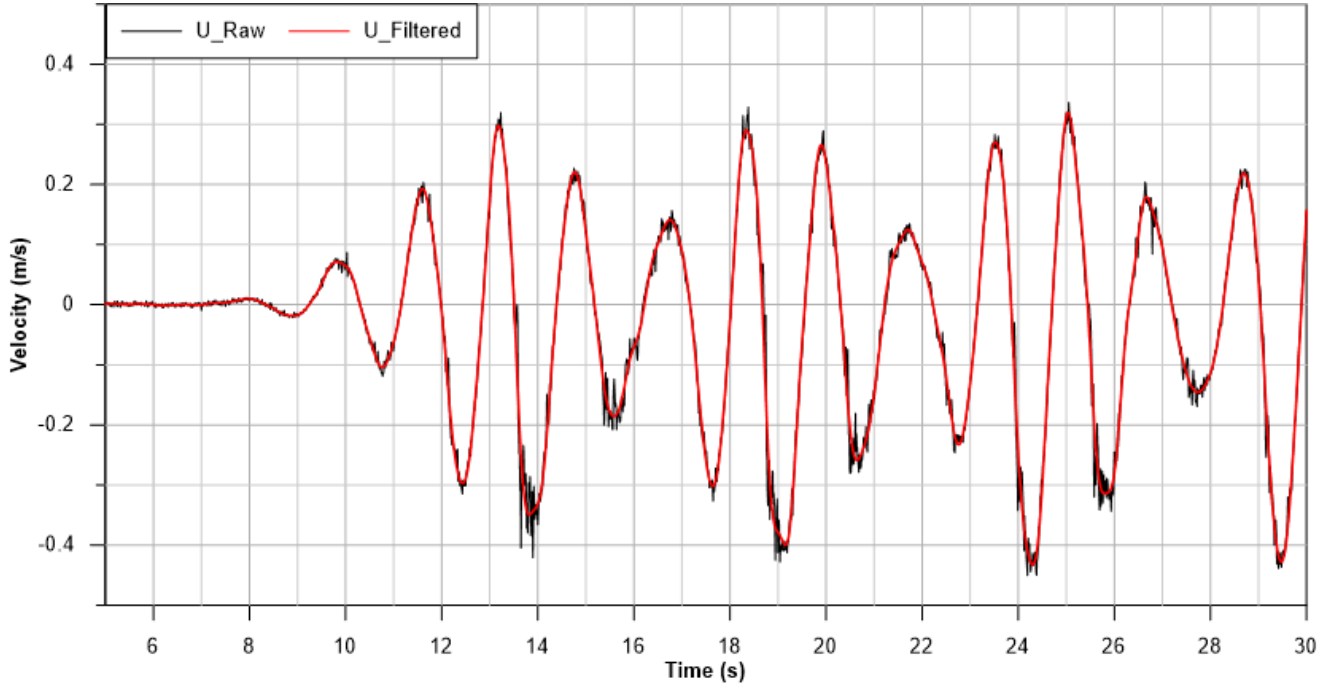
Despiked: Horizontal U Velocity

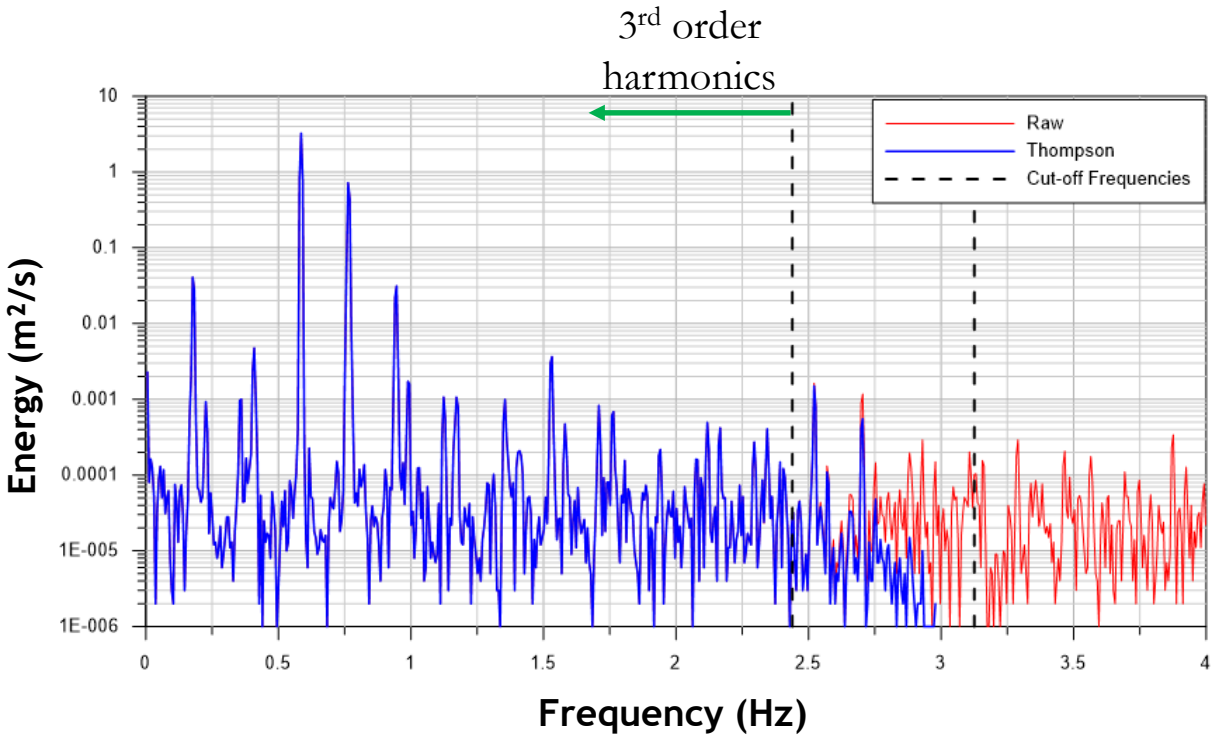


Methodology

- **Step 1: Data quality:** seeding material (TiO_2 + circular source);
- **Step 2: Despike method:** Goring and Nikora (2002);
- **Step 3: Thompson filter:** Thompson (1983);

Filtered: Horizontal U Velocity





Methodology

- **Step 1: Data quality:** seeding material (TiO_2 + circular source);
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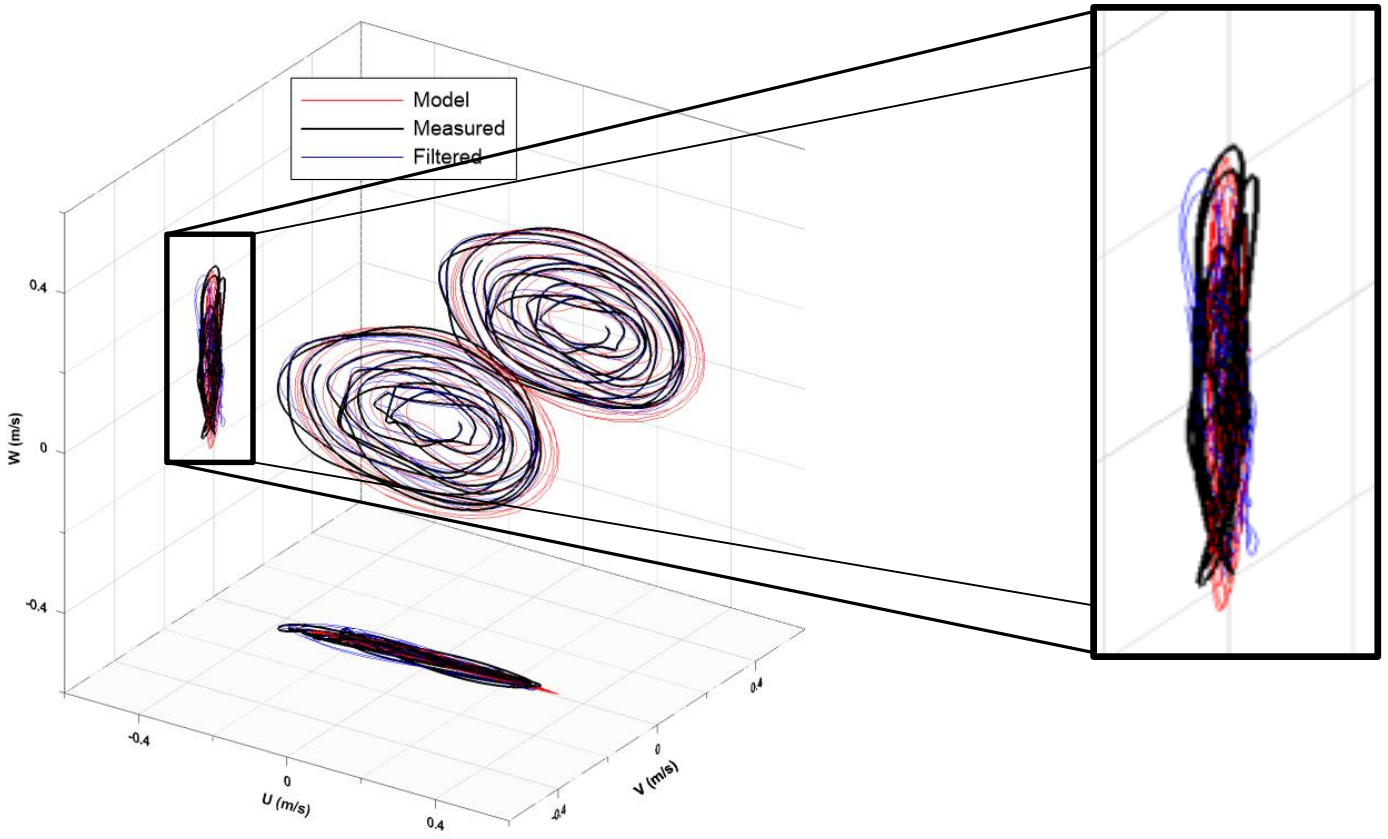
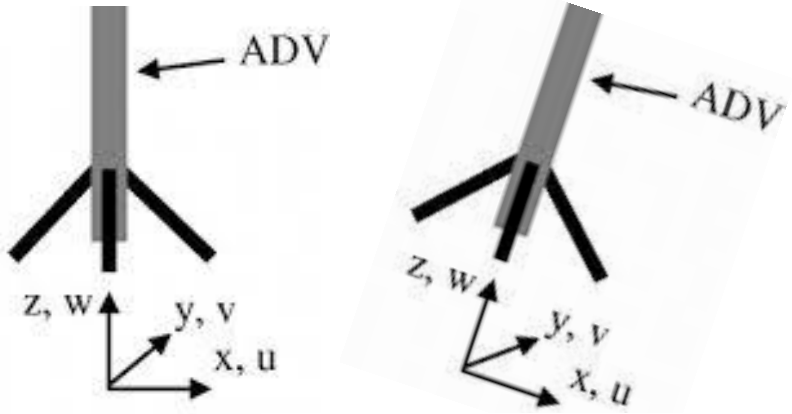
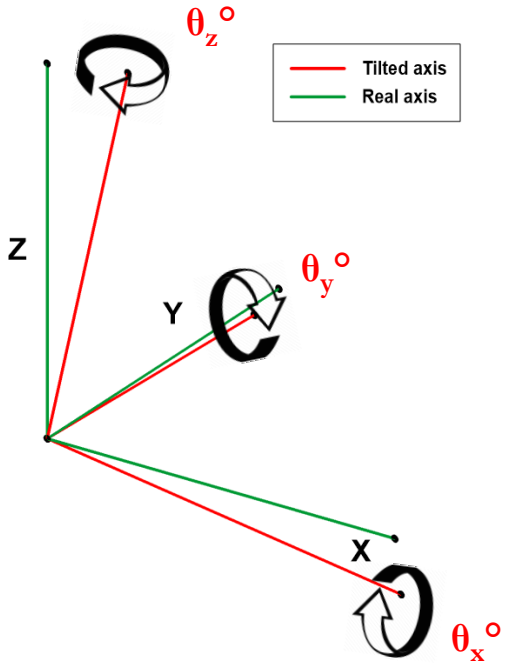
- **Step 4: ADV tilt correction:** Neves *et al.* (2012).







Methodology

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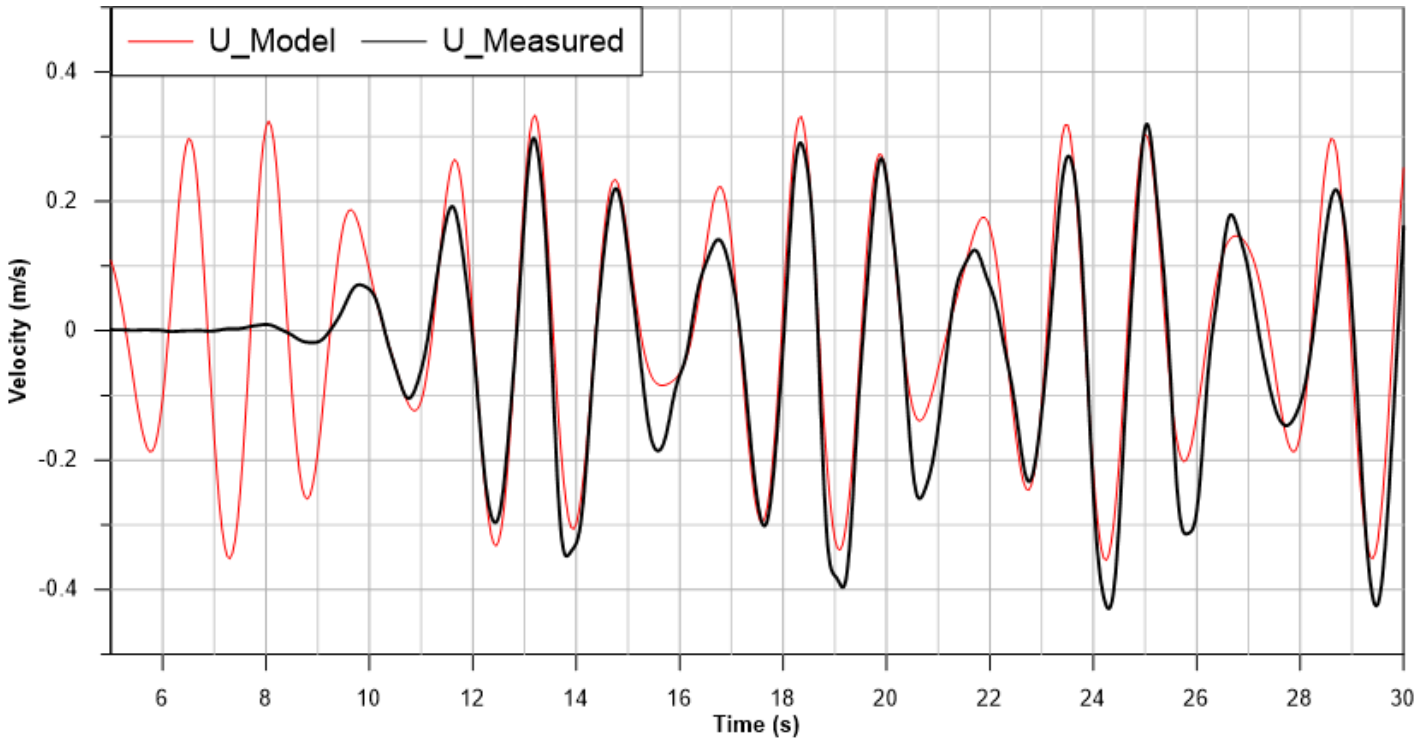
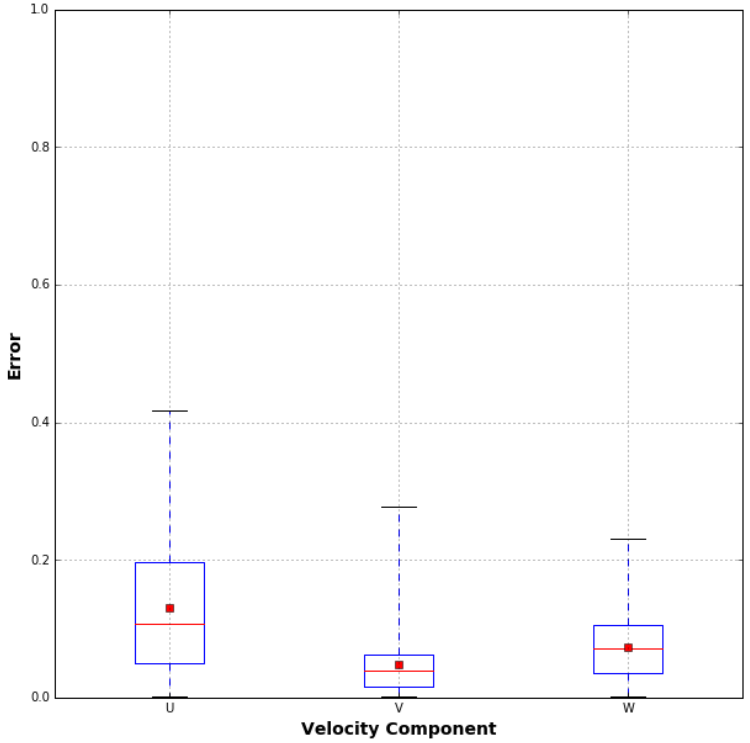
- **Final result:**

Horizontal U Velocity

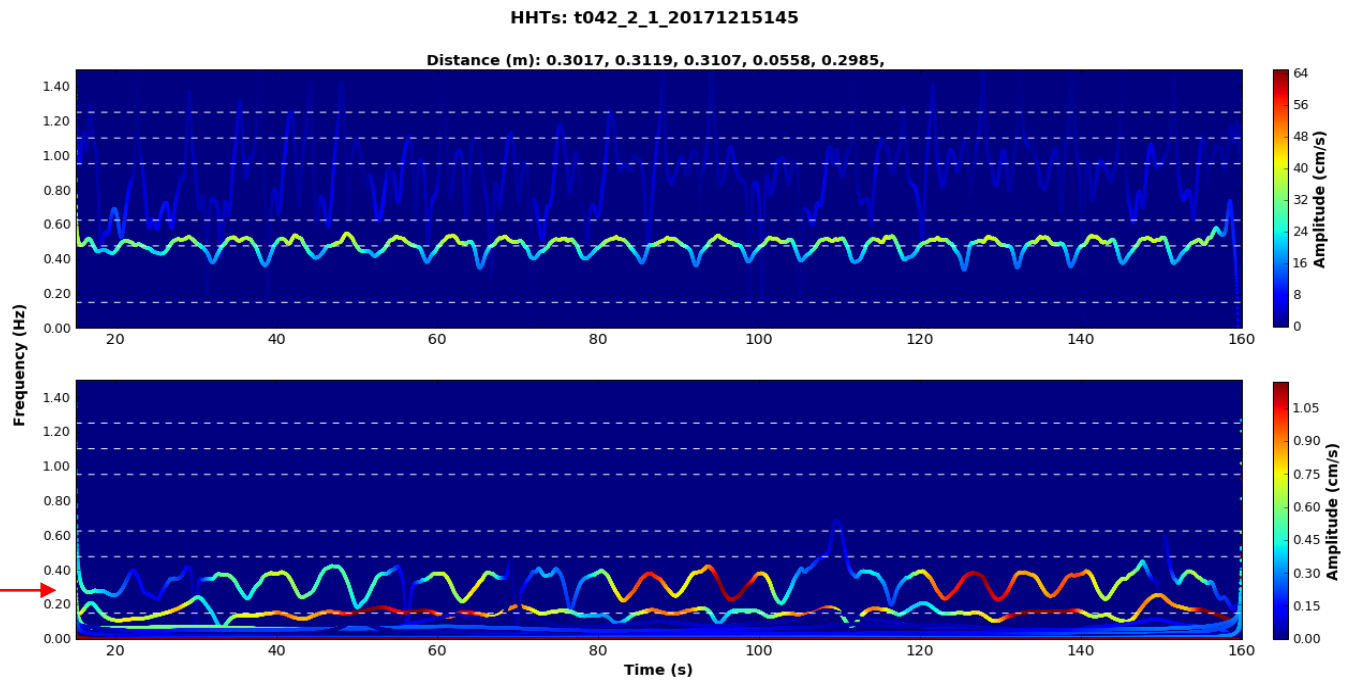


Error Analysis



Conclusions

- Infragravity wave detection with ADV:
  - HHT
  - MEMD
- Discussion:
  - Can reflected waves be quantified?



Reflection?