Ludwig-Franzius-Institut
für Wasserbau, Ästuar- und
Küsteningenieurwesen

Leibniz
Universität
Hannover

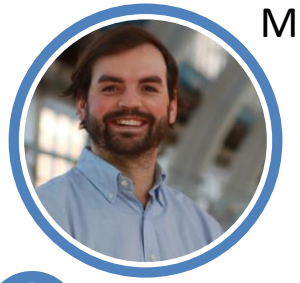
New Insights into Wave-Current Interactions in the German Bight

RAVE Workshop 2023 – 11.05.2023

M.Sc. Thilo Grotebrune
M.Sc. Lukas Fröhling
Prof. Dr.-Ing. Arndt Hildebrandt

Ludwig-Franzius-Institute for Hydraulic, Estuarine and Coastal Engineering, Leibniz Universität Hannover,
www.lufi.uni-hannover.de, grotebrune@lufi.uni-hannover.de

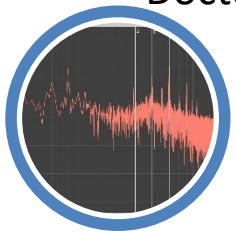
Thilo Grotebrune,
M.Sc.



Internship KKP
(Jakarta/Bali – TwinSea Project)

Project Engineering
and supervision (HH)

Doctoral Candidate
(LUH)



Masters Degree (LUH)

Oversea Semester

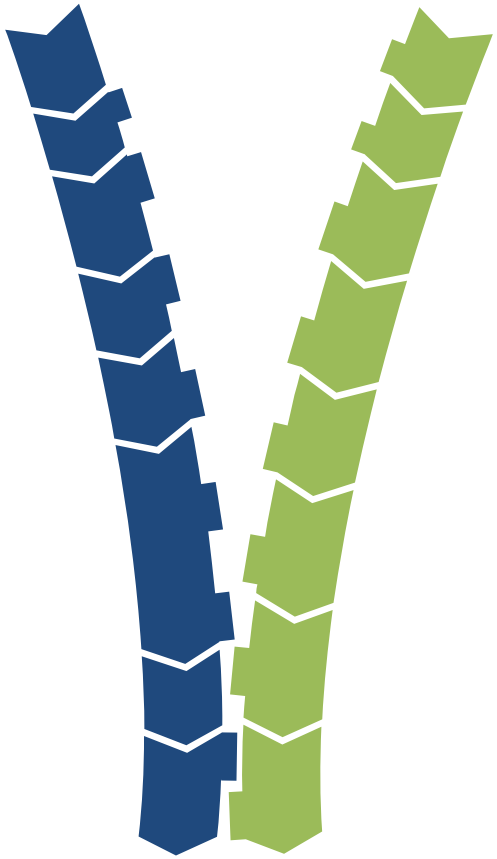
RAVE Workshop 2023

Outline

Framework

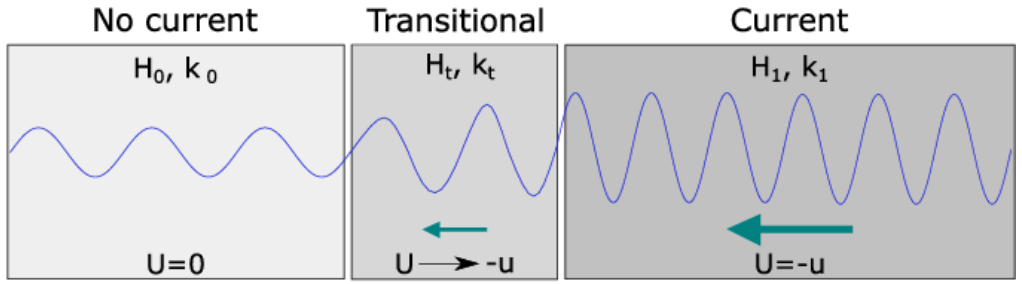
- Coastal areas are dynamically influenced by various factors
- Coastal processes shape coastlines, impact ecosystems, and affect human activities
- wave-current interactions also directly impact offshore operations
- Offshore operations rely on safe and efficient now- and forecasts
- Requirement of a deep understanding of wave-current interactions

➢ **Minimization of risks** associated with offshore activities



Research Focus

Opposing currents result in an increasing wave height and decreasing wave length and vice versa



(Draycott et al., 2018)

wave kinematics changed by currents
- wave length
- wave height
- wave energy
-...

mean velocity profiles altered by wave motions

turbulent characteristics altered by wave motion

radiation stresses

bed shear stress

Research Focus

Wave kinematic changes by currents have been investigated by

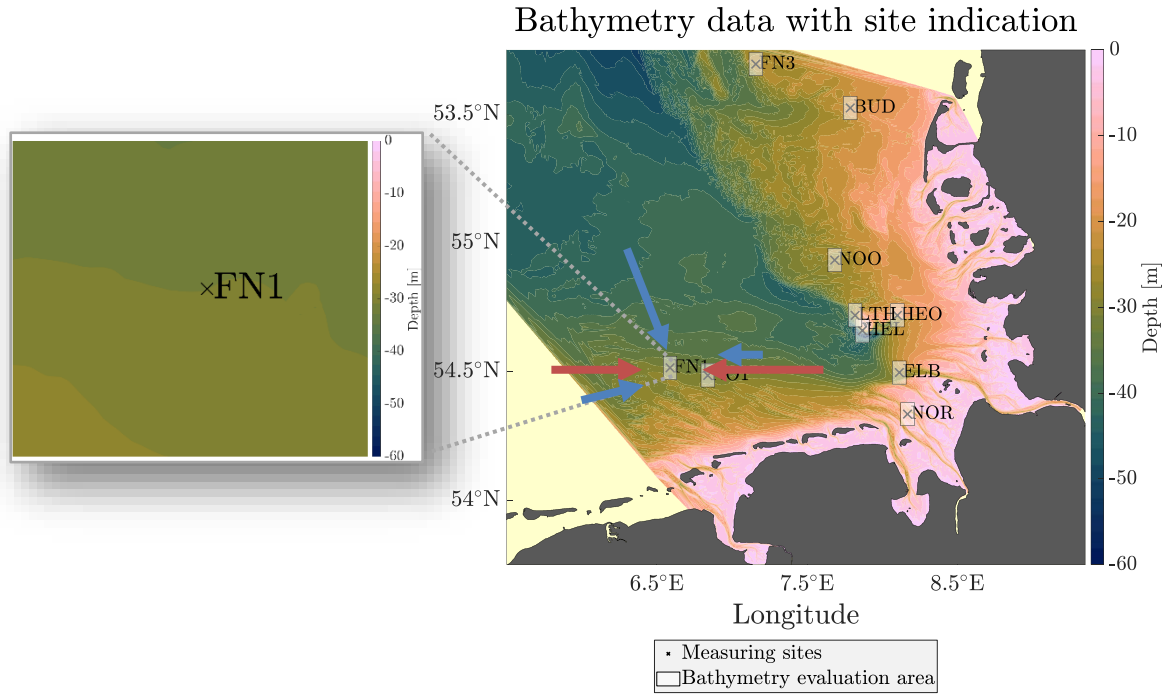
- Theoretical approaches
- Analytical models
  - Phase-solving models (Boussinesq)
  - Phase-averaged models (e.g. SWAN)
- Experimental data
- Field data

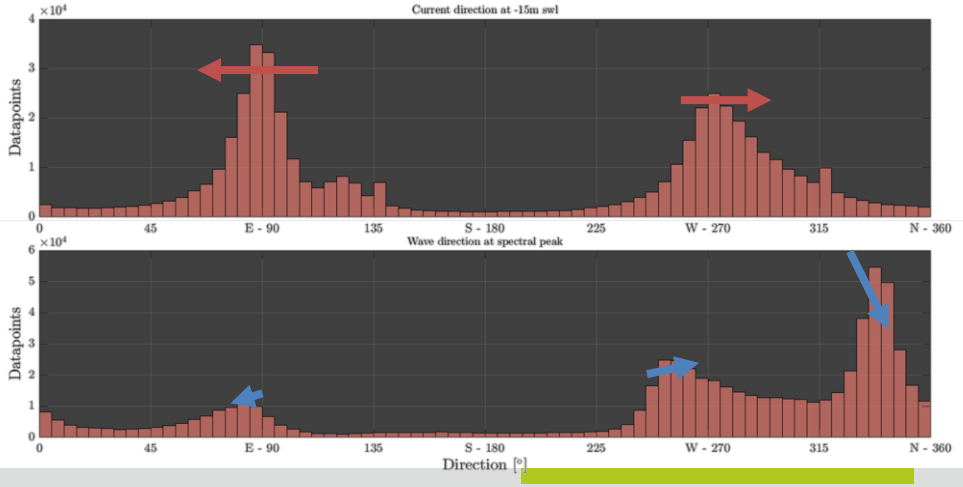
- Often lack of validation with field data
- directionality unconsidered (collinear/orthogonal)
- wave transformation not research topic

Methodology

Data & Site Specific Conditions

- Multiple quality checked datasets provided by BSH
  - 2004 – today (ADCP / DWR / WIND)
- limiting investigation to FN1
  - Longest current and wave measurements
  - Low depth variation of bathymetry
- Mean current direction
  - East to West
- Mean wave direction
  - North-West to West



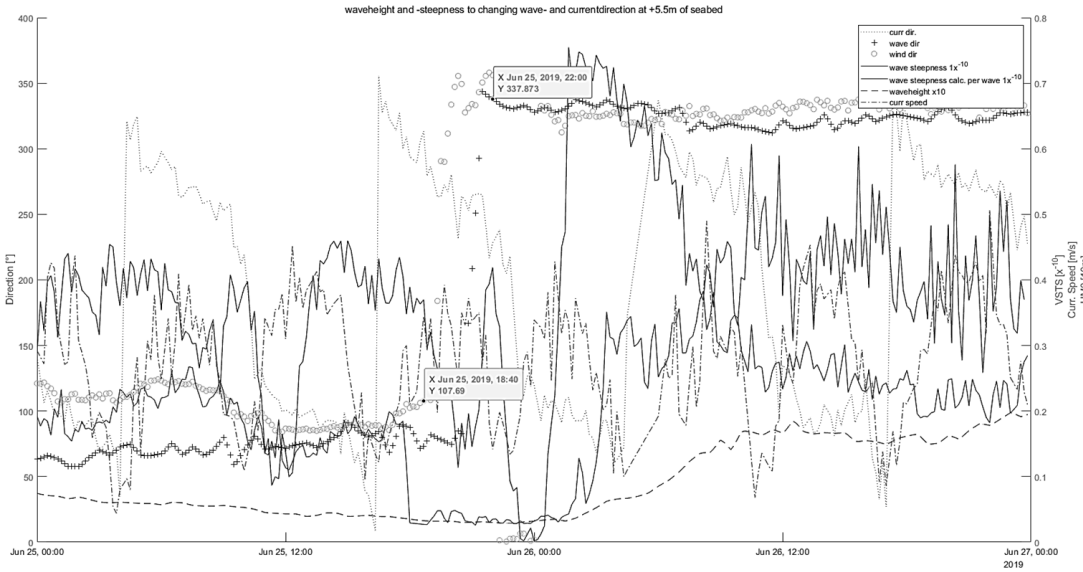


Dimensionality reduction

Dynamical processes induced by

- Bathymetry
- Depth
- Salinity
- Temperature
- Wind, Wave, Current

- Dimensionality reduction trough neglection
  - examining specific events



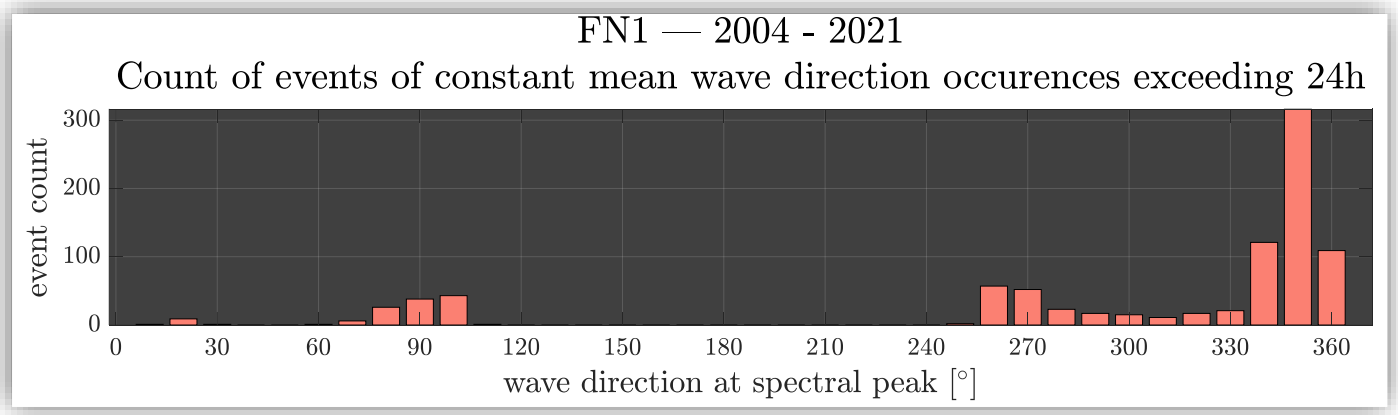
➢ Filter method considering constant states only

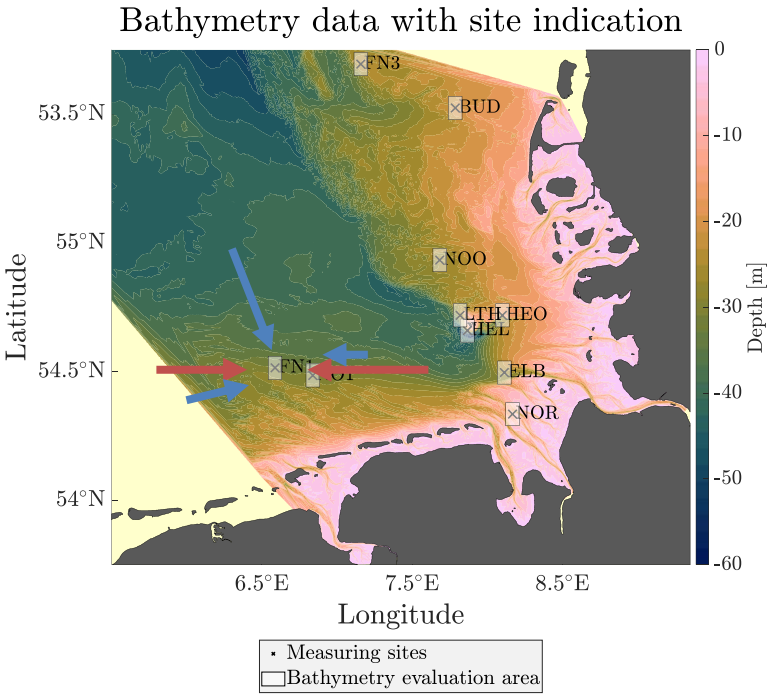
- e.g. constant mean wave direction > 24h

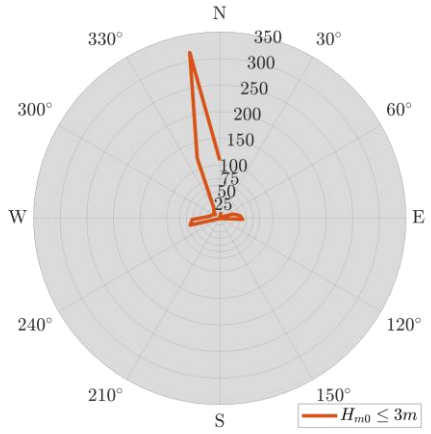
Filtered event count

- Apply filter method considering constant states only
  - constant mean wave direction $\geq 24h$
  - $H_{m0} \leq 3m$

- Constant wave occurence correlates with mean wave direction at site FN1
- No events found bewteen 110° – 240°
  - Lack of waves propagating northward
- Total event count: 887





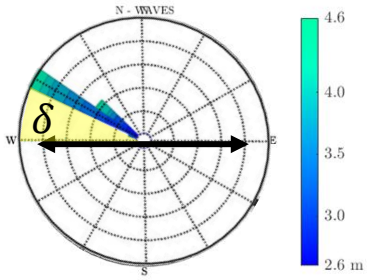


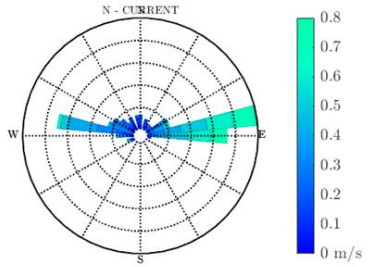
Results

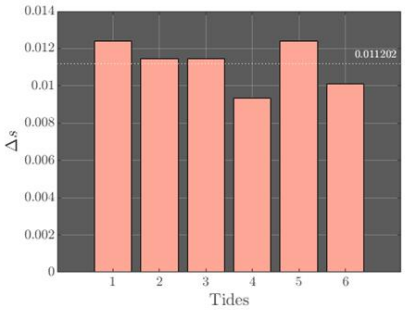
Results - Quantify wave kinematic changes

- Wave steepness as the indicator of wave transformation

$$s = \frac{H_{m0} * 2\pi}{T_z^2 * g} \rightarrow \Delta s = \frac{H_{m0,flood}}{\lambda_{flood}} - \frac{H_{m0,ebb}}{\lambda_{ebb}}$$

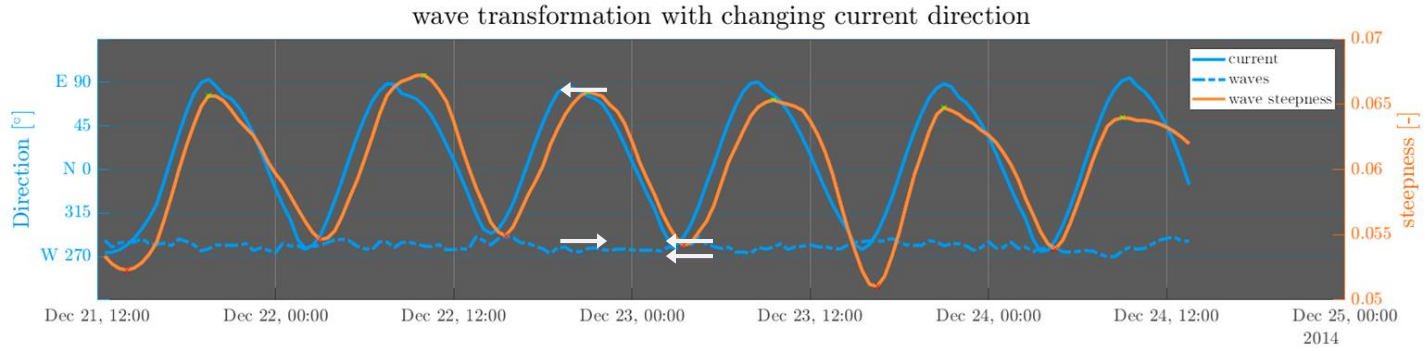






- Peak steepness at opposing current
- Lowest steepness at following

➢ Confirmation of theory



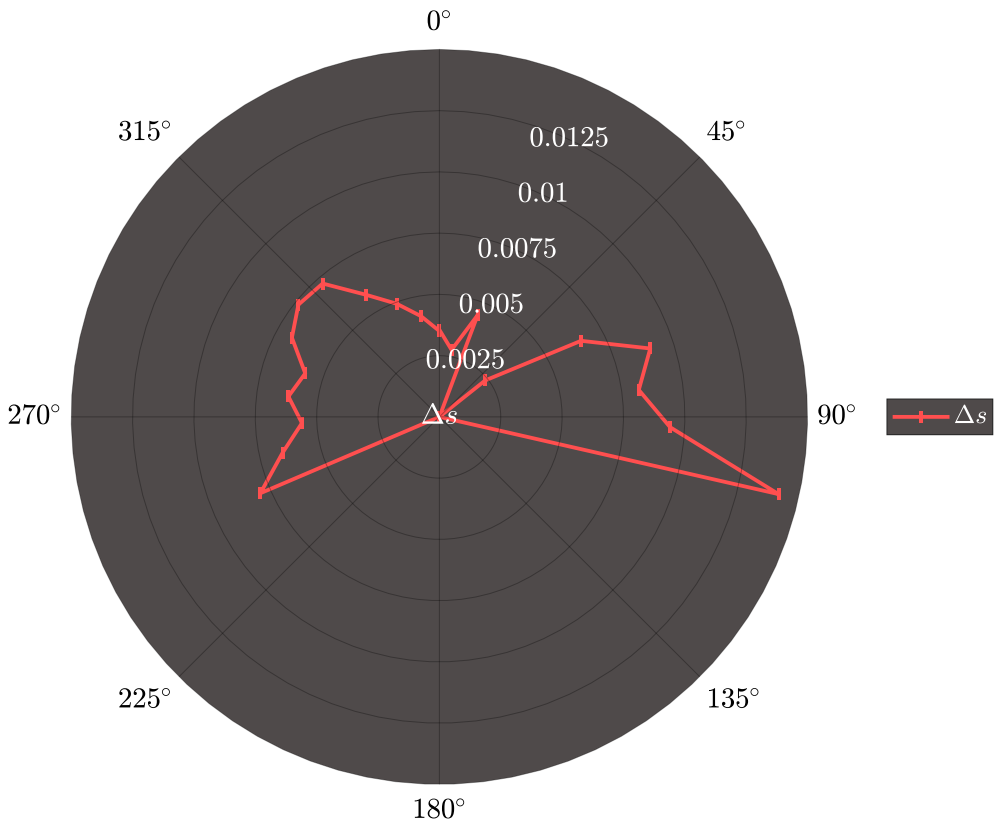
➢ Apply sectorial for all filtered occurences
  - mean steepness differences per event

Results - Quantify wave kinematic changes

- Wave steepness as the indicator of wave transformation

$$\Delta s_{mean} = \sum \frac{\Delta s_{tide}}{N_{tide}}$$

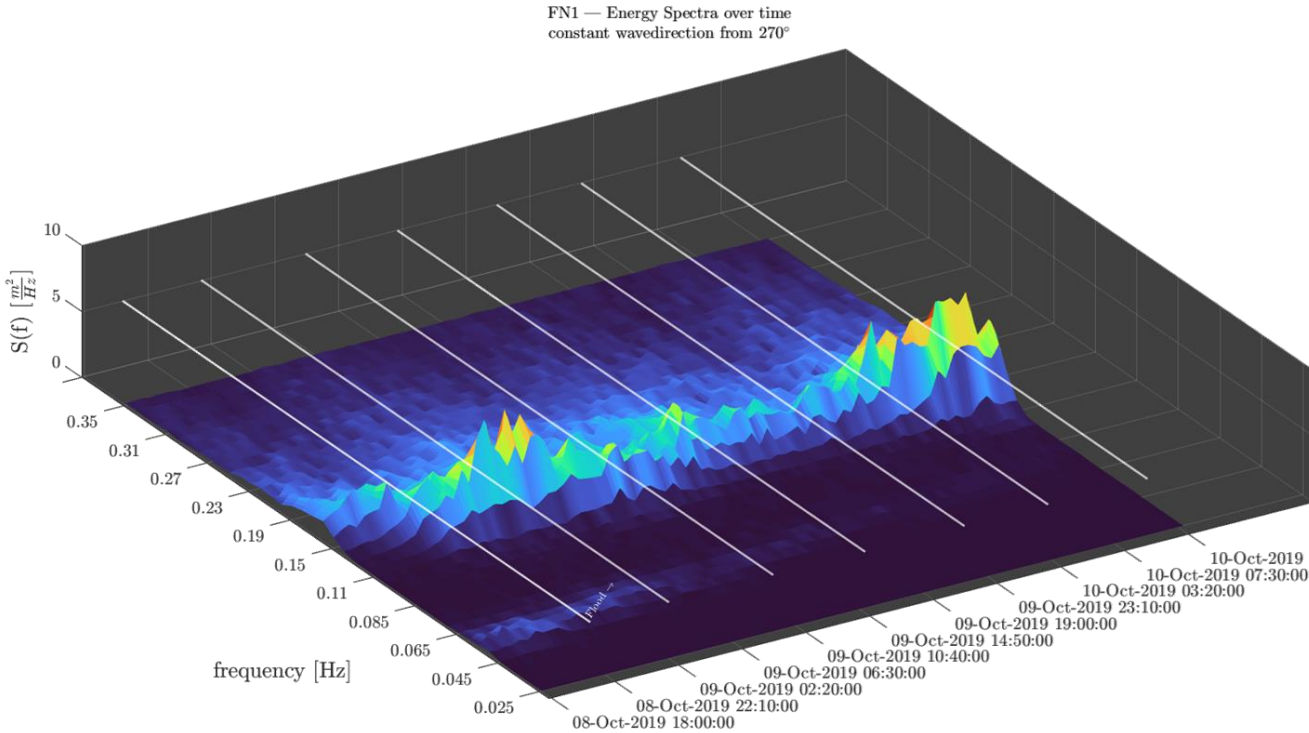
- mean steepness difference per event and sector
  - Impact decreases with angle
  - Current influence on steepness is minimal at $\delta \approx 90°$
  - ➢ Quantification requires additional gap filling

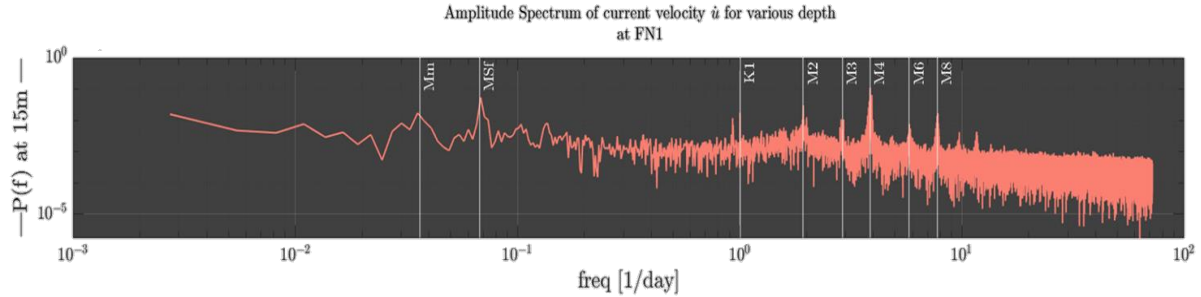


Outlook & Research Link

Outlook

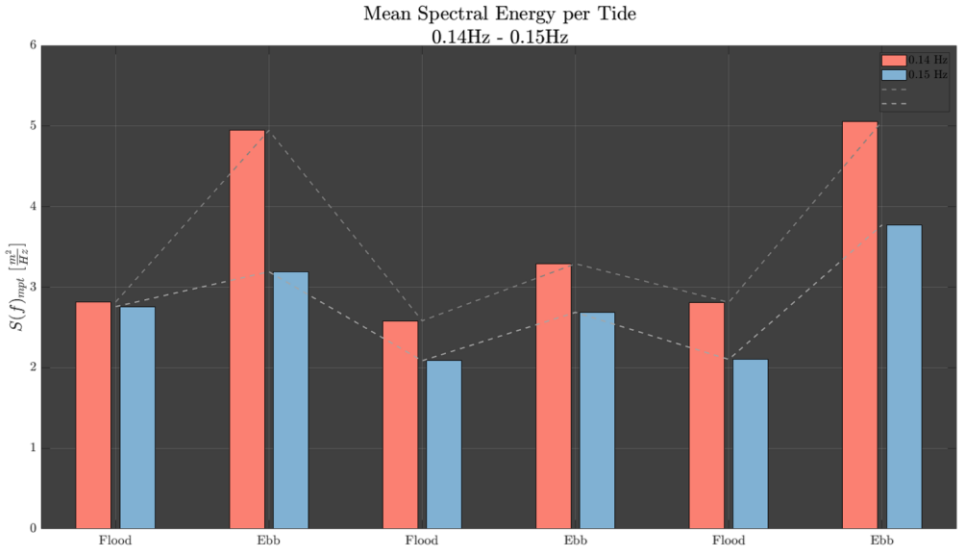
- Doppler shift theory applies
- Spectral frequency analysis to identify frequency shifts
  - Higher frequencies more likely influenced
  - $T_z \xrightarrow{freq} T_p$
- Tidal wave superposition magnifies the influence on wave transformation
  - Higher velocities → higher amplification





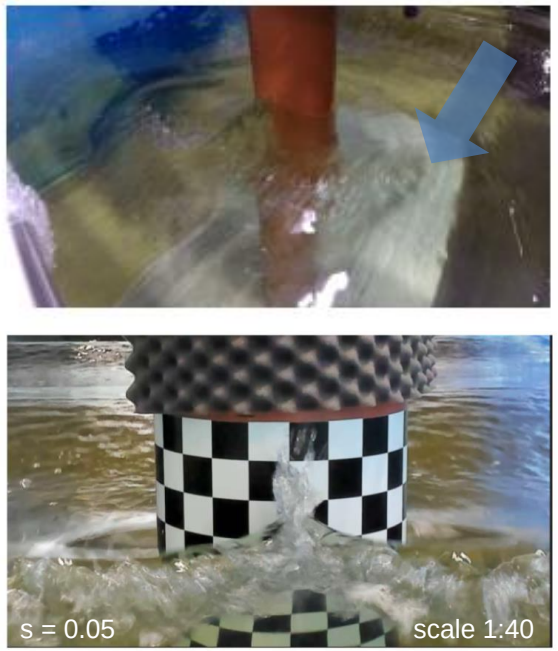
Outlook

- Automation extensive analysis to all sites
  - spectral energy transfer; frequecy fluctuations
    - Case study | identification of significance
  - Site comparison
    - Influence of location-dependent boundary conditions
- Principals of directionality in open waters
  - validation of previous approaches
- Implemetation of neural-network-based framework



Research Link

- Offshore Work Vessel in Motion
- Diffraction related wave energy behind monopile leads to amplification
  - → wave steepness dependency
  - → potential harm for crew safety due to wave run-up phenomenon



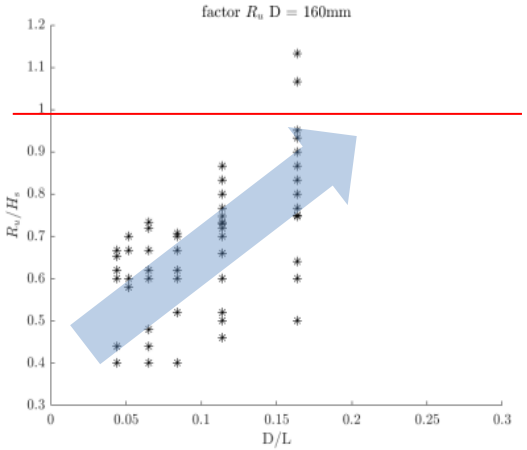
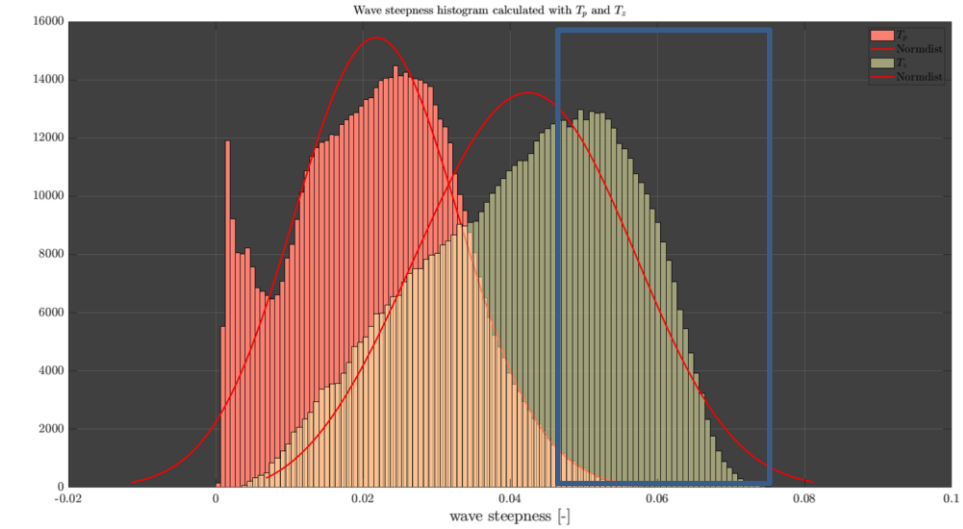


Abbildung 4.2.10: R_u/H_s Daten für D = 160mm



RAVE
RESEARCH AT ALPHA VENTUS

Supported by:

Federal Ministry
for Economic Affairs
and Climate Action

on the basis of a decision
by the German Bundestag

Projektträger Jülich
Forschungszentrum Jülich

BSH
BUNDESAMT FÜR
SEESCHIFFFAHRT
UND
HYDROGRAPHIE

Fraunhofer
IWES

Thank you!

Sources

Draycott, Sam & Pillai, Ajit & Ingram, David & Johanning, Lars. (2019). Resolving combined wave-current fields from measurements using interior point optimization. Coastal Engineering. 149. 4-14. 10.1016/j.coastaleng.2019.03.008

Xuan Zhang, Richard Simons, Jinhai Zheng, Chi Zhang. (2022). A review of the state of research on wave-current interaction in nearshore areas, Ocean Engineering, Volume 243, https://doi.org/10.1016/j.oceaneng.2021.110202.

• RAVE - Research at alpha ventus

- Accompanying research initiative at the alpha ventus offshore test wind farm since 2007
- More than 35 projects funded by the Federal Ministry for Economic Affairs and Climate Action (BMWK) with +120 mill. €
- Essential cornerstone in the development of offshore wind energy in Germany
- A long-term and unique data set of in-situ measurements is accessible in the RAVE data archive operated by the Federal Maritime and Hydrographic Agency (BSH) https://serviceportal.bsh.de/BSHPortalDMZ/userRoles.jsf
- Extensive documentation of the measurement program and design data for one turbine type are also available for research
- alpha ventus and RAVE are used as blueprint for offshore wind power demonstration worldwide
- In addition to the long-term measurement program, special measurement campaigns (e.g. underwater sound, nacelle lidar, …) were also carried out over a limited period of time by industry and academic partners.

For more information: www.rave-offshore.de

Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

Projektträger Jülich Forschungszentrum Jülich

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

Fraunhofer IWES

RAVE RESEARCH AT ALPHA VENTUS