Performance of wave breaker formulations in SWAN

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Zeeland. European Space Agency (2020).

General idea: exploring the importance of frequency dependence on surf breaking

- Decreasing depth: surf breaking

- How to model surf breaking? Wave breaker formulations
- Various models:
  - Battjes-Janssen (1978);
  - BKD (2015);
  - Van der Westhuysen (2009)
- But… no dependence on wave frequency
- Is this justified?

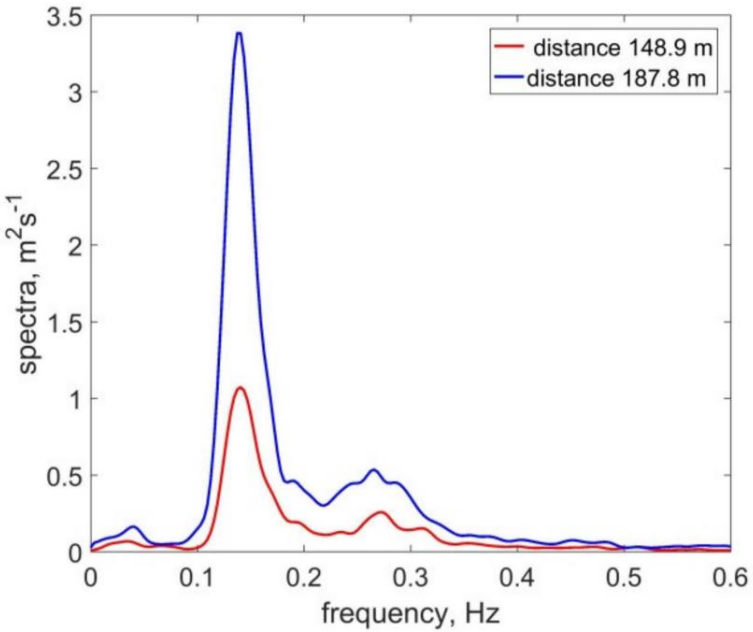
▲ *Surf breaking*. The New York Times (2022).

General idea: exploring the importance of frequency dependence on surf breaking

- What do we need?

1

<u>wave spectra:</u>
simulated &
measured



◀ Saprykina (2022)

Without contributions of breaking!

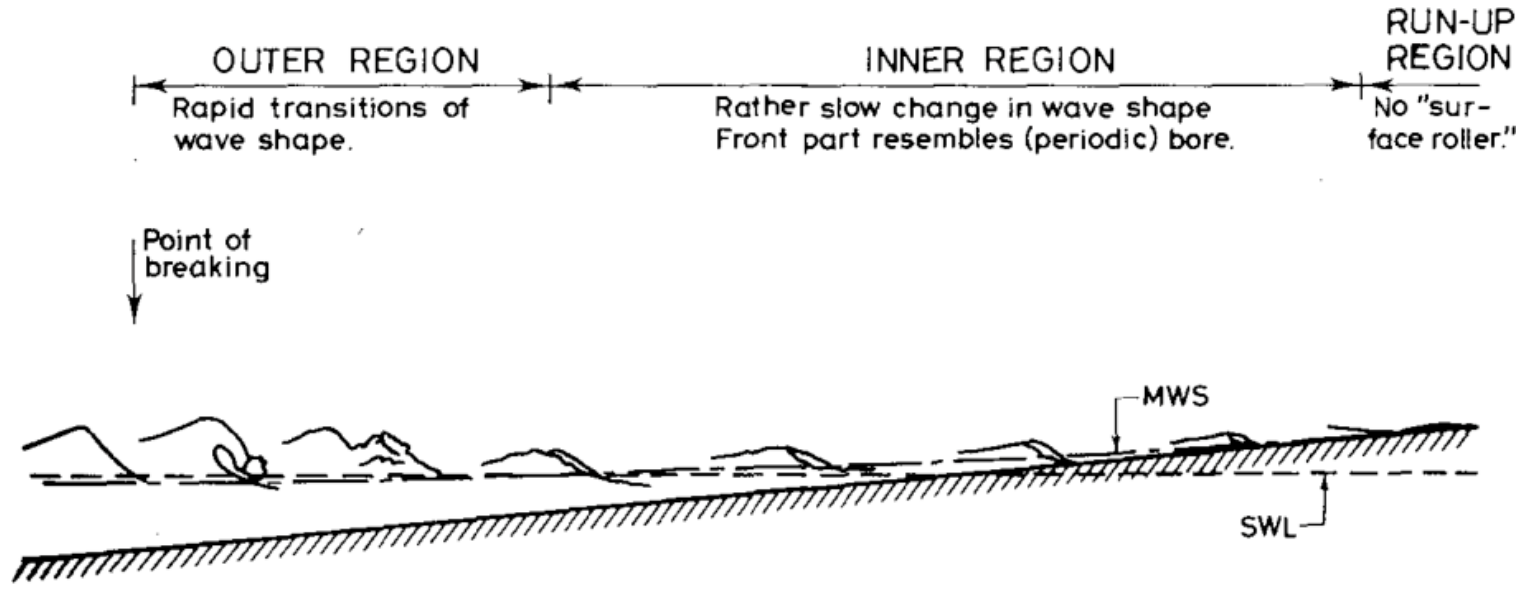
2

<u>dissipation coefficient</u>

$$\alpha_n = \frac{S(x_{start} + \Delta x)_{calc} - S(x_{start} + \Delta x)_{meas}}{S(x_{start})_{meas}(2\Delta x)}$$

Literature review: summary

- **Chen et al. (1997):** dissipation increases at high frequencies, but counteracted by influx of energy from increased nonlinear energy transfer
- **Meza et al. (2000):** dissipation increases at high frequencies, energy gain below peak frequency
- **Kuznetsov and Saprykina (2004):** distinction between *inner* and *outer* surf zone
  - outer: dissipation almost indepdent of frequency
  - inner: quadratic or selective frequency dependence

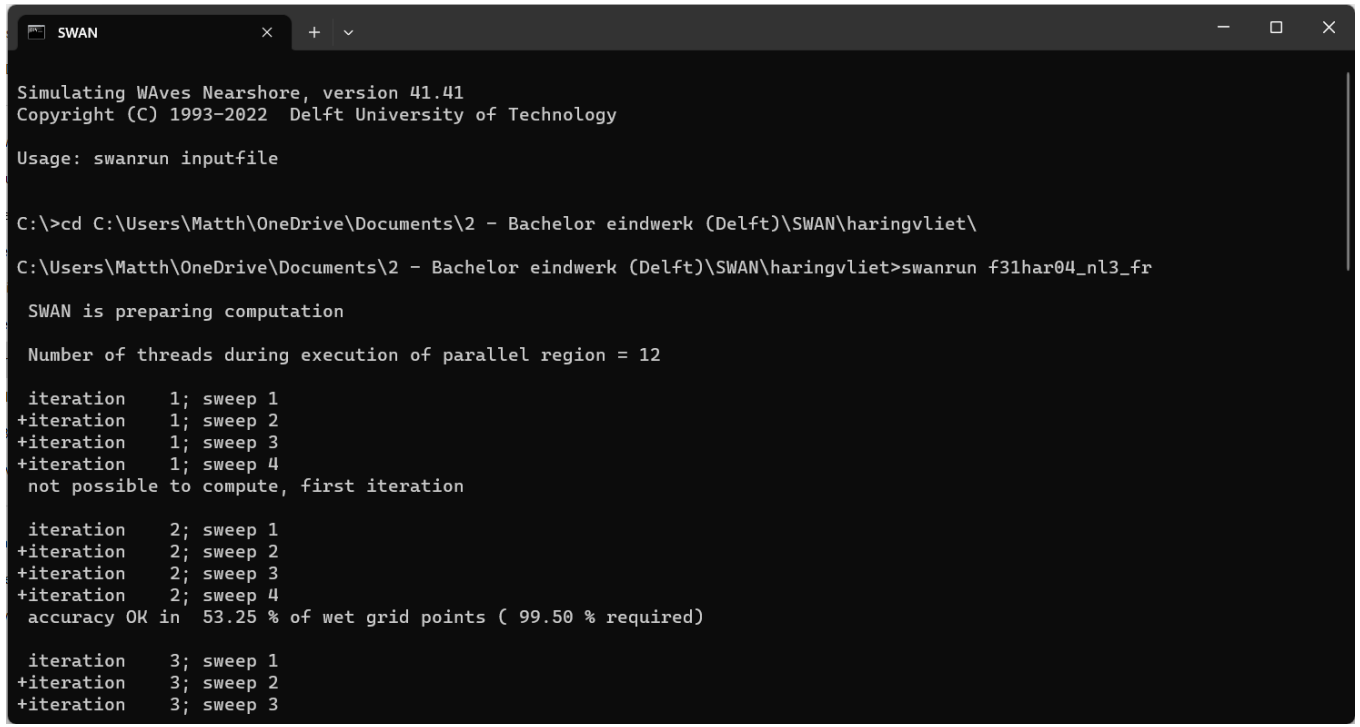


◄ *Inner & outer surf zone*. Svendsen (1978).

Approach (I): simulations in SWAN

- SWAN 41.41 for Windows
- *Simulating WAves Nearshore*
- Developed and supported by TU Delft Fluidmechanics Section
- Command line interface based program
- In this project: calculate wave spectra (1D and 2D)

SWAN
Simulating WAves Nearshore



▶ *Typical SWAN interface*

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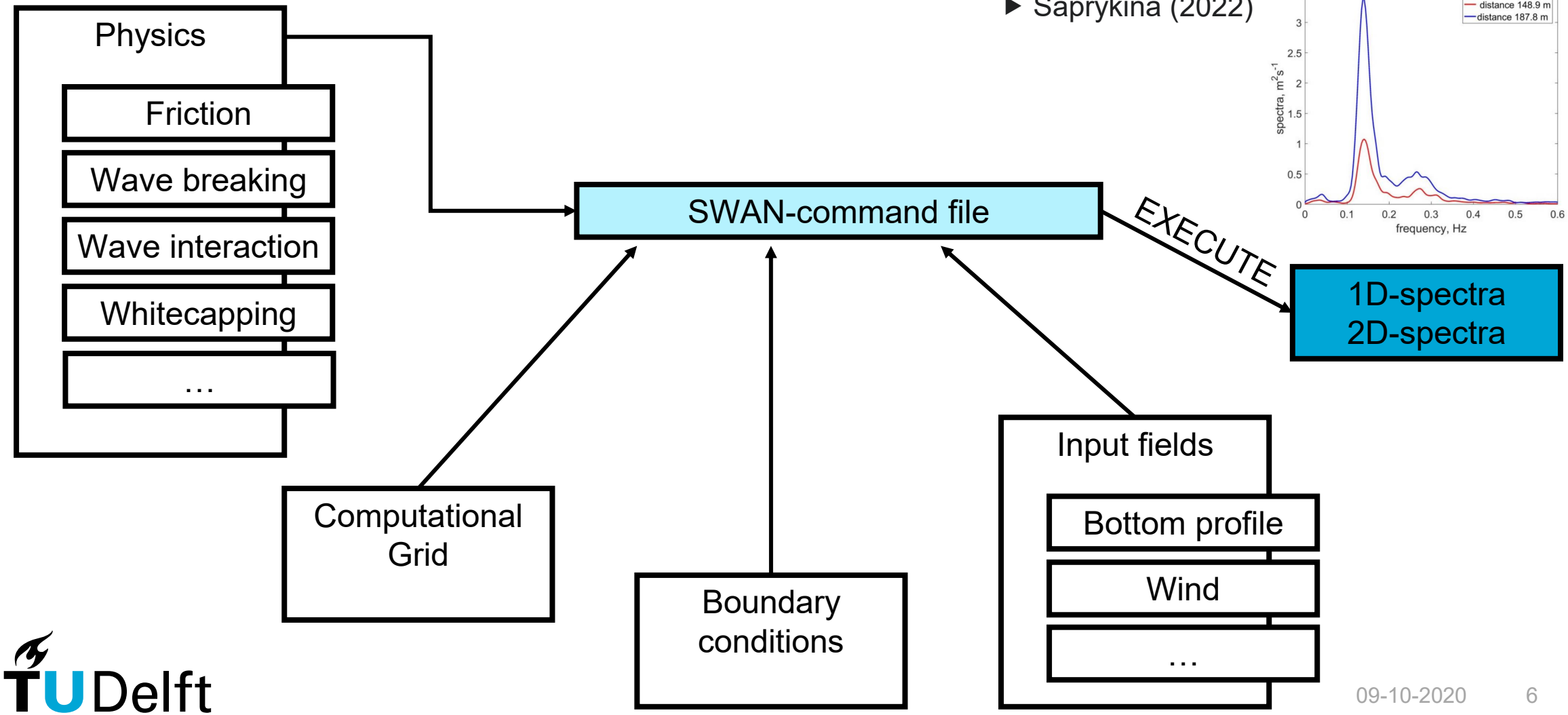
Approach (I): simulations in SWAN – 'SWAN cookbook'



▶ Saprykina (2022)

n SWAN – ‘SWAN cookbook’

f31har04_nl3_fr.swn

Bestand Bewerken Weergeven

```
$ WL   = + 2.10
$ Hs   = 3.53 m
$ Tm01 = 6.9 s
$ Tp   = 8.3 s
$
$ --|-------------------------------------------------------------|--
$   | This SWAN input file is part of the bench mark tests for     |
$   | SWAN. More information about this test can be found in       |
$   | an accompanied document.                                     |
$ --|-------------------------------------------------------------|--
$
$*******************MODEL INPUT************************
$
SET LEVEL 2.10
$
CGRID 6960.2 0. 0. 14789.8 22000. 98 88 CIRCLE 36 0.0521 1. 31
$
INPGRID BOTTOM 0. 0. 0. 87 116 250. 250. EXC -7.0
READINP BOTTOM .1 'f31hari.bot' 1 6 FORMAT 1
$
WIND 15. 8.8
$
BOU SIDE W CCW CON FILE 'f31har04.bnd' 1
$
GEN3
OFF WINDGROWTH
OFF WCAPPING
OFF QUADRUPL
OFF BREAKING
FRIC JONSWAP
TRIAD DCTA BIPHASE DEWIT
$
$*************************************************************
$
POINTS 'BUOYS' FILE   'f31hari.loc'
TABLE  'BUOYS' HEAD   'f31har04.tab' DIST DEP HS RTP TM01 TM02 FSPR DIR SETUP
SPEC   'BUOYS' SPEC1D 'C:\\Users\\Matth\\OneDrive\\Documents\\2 - Bachelor
eindwerk (Delft)\\SWAN\\haringvliet\\results_nl3_fr\\1D_DEWIT.txt'
SPEC   'BUOYS' SPEC2D 'C:\\Users\\Matth\\OneDrive\\Documents\\2 - Bachelor
eindwerk (Delft)\\SWAN\\haringvliet\\results_nl3_fr\\2D_DEWIT.txt'
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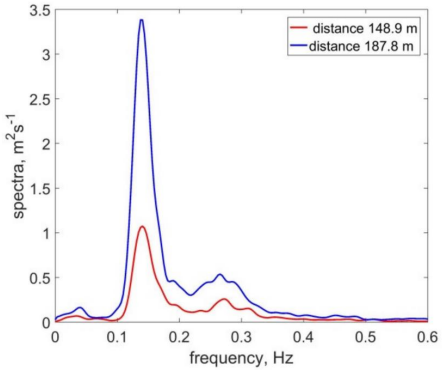
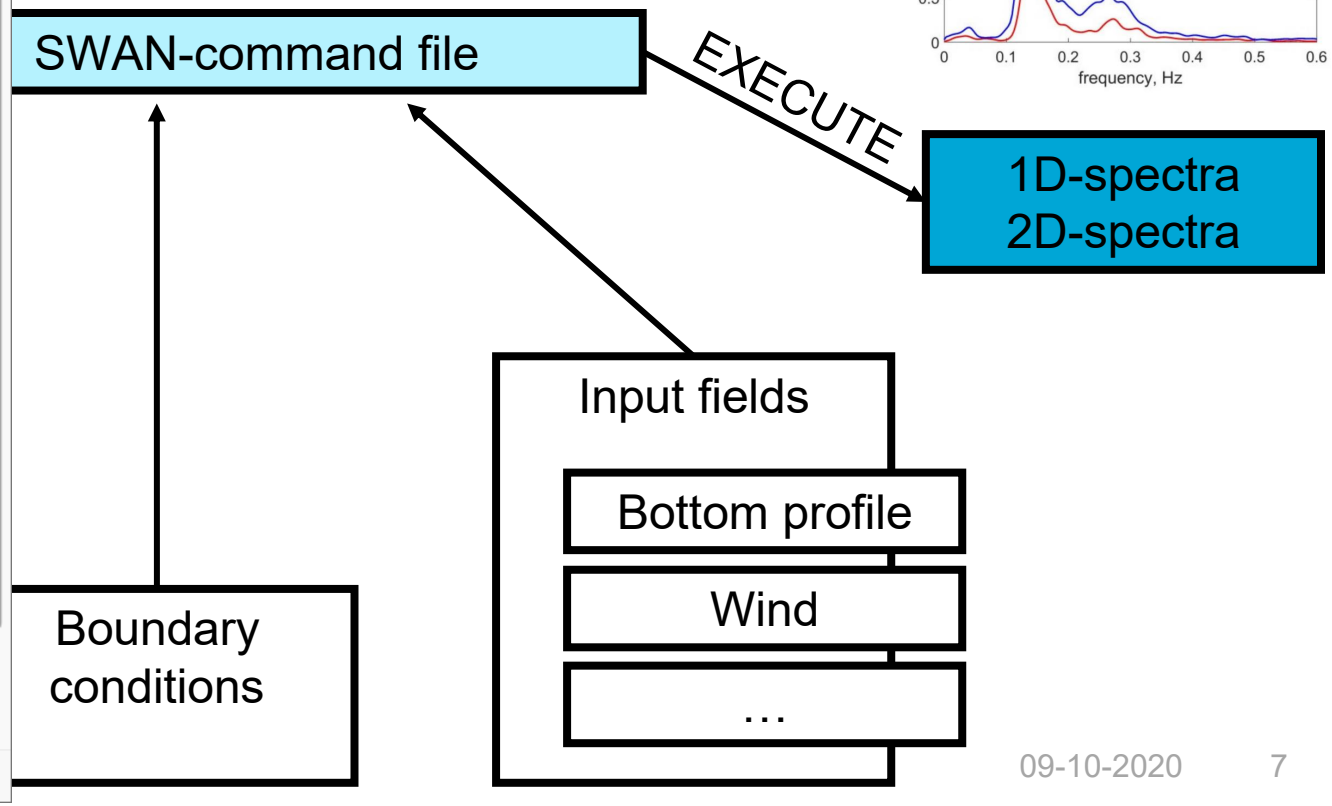
- Saprykina (2022)

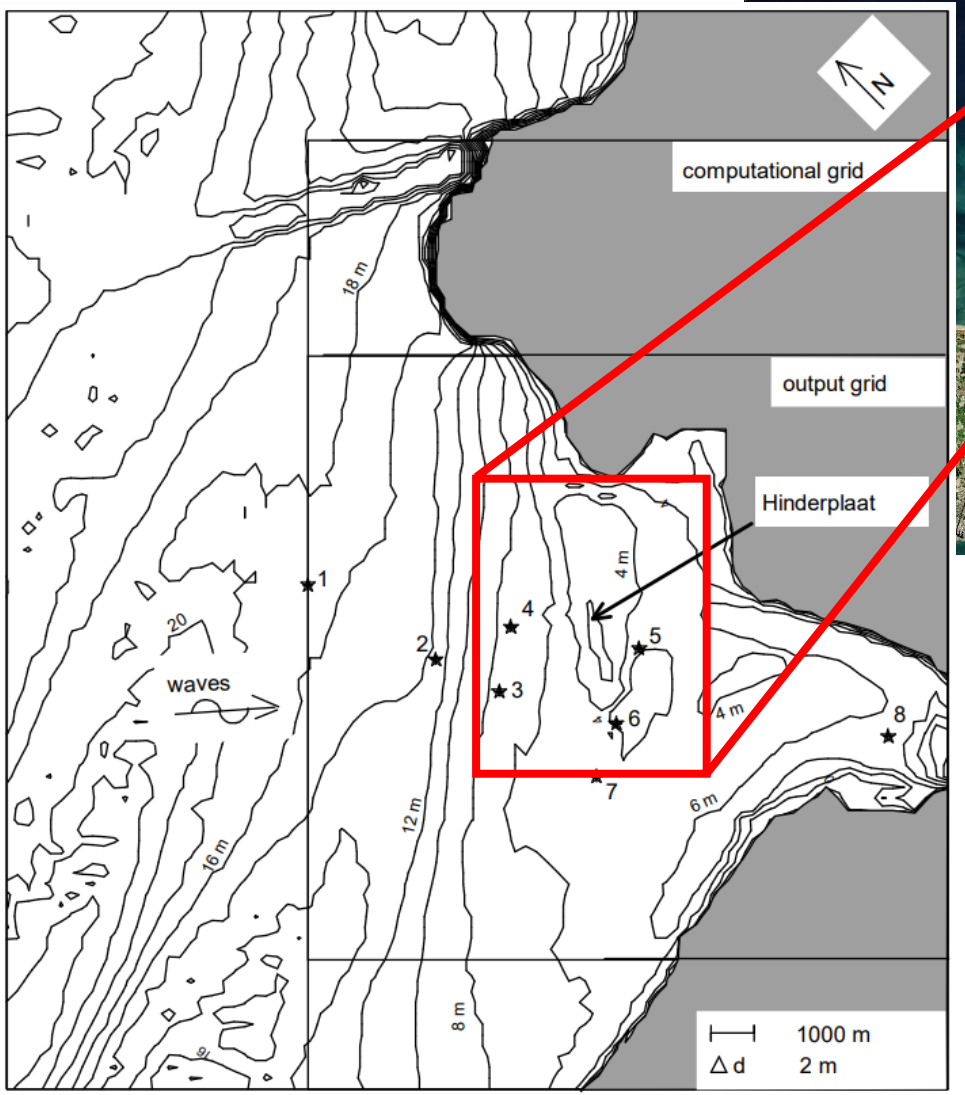




Approach (II): comparison with observations

- Area of study: Haringvliet estuary
- Hinderplaat shoal
- Observations (wave spectra) available during 1982 storm
- Stations before (3, 4) and after (5, 6) the shoal
- How to conduct comparison? <u>Dissipation coefficient</u>

$$\alpha_n = \frac{S(x_{start} + \Delta x)_{calc} - S(x_{start} + \Delta x)_{meas}}{S(x_{start})_{meas}(2\Delta x)}$$



▲ *Zeeland*. European Space Agency (2020).

◀ *Close-up of Hinderplaat shoal*. Xi advies bv (n.d.)

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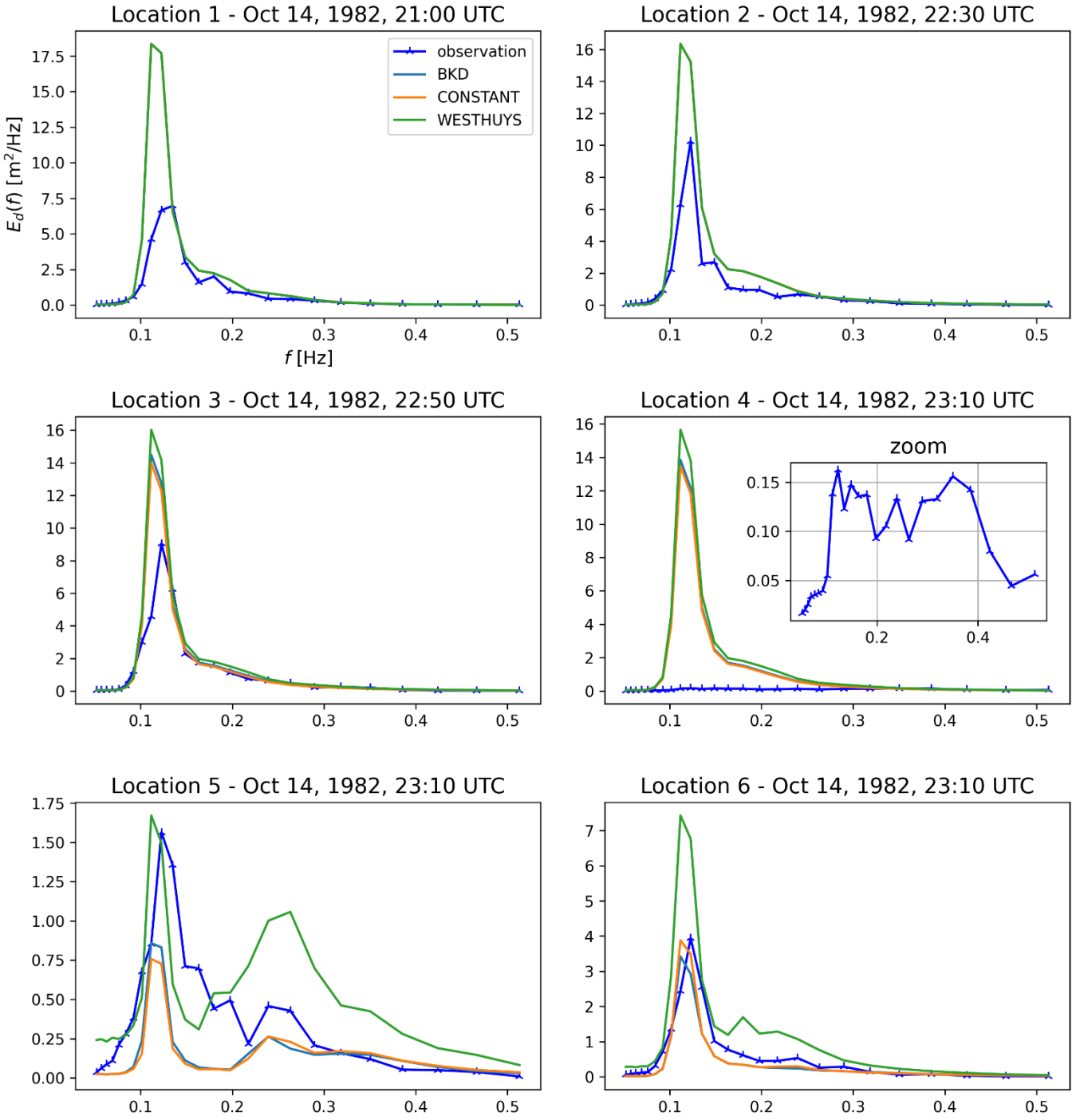
Current performance of breaking formulations

- Simulations reproduce position of peak @ location 1, 2, 3, 6
- Spectra @ location 5 more irregular (breaking!)
- Location 4 is weird… (more later on)



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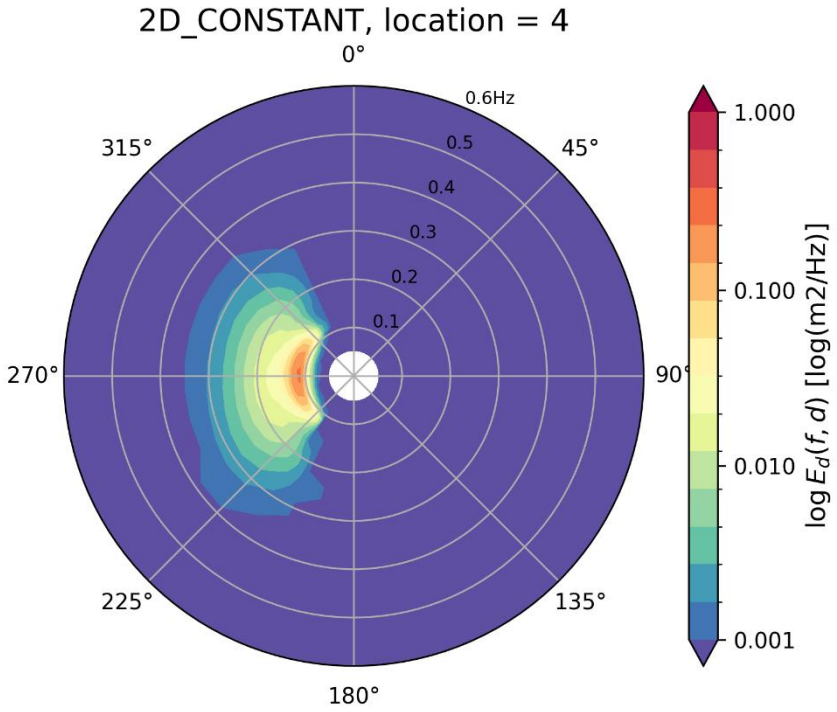
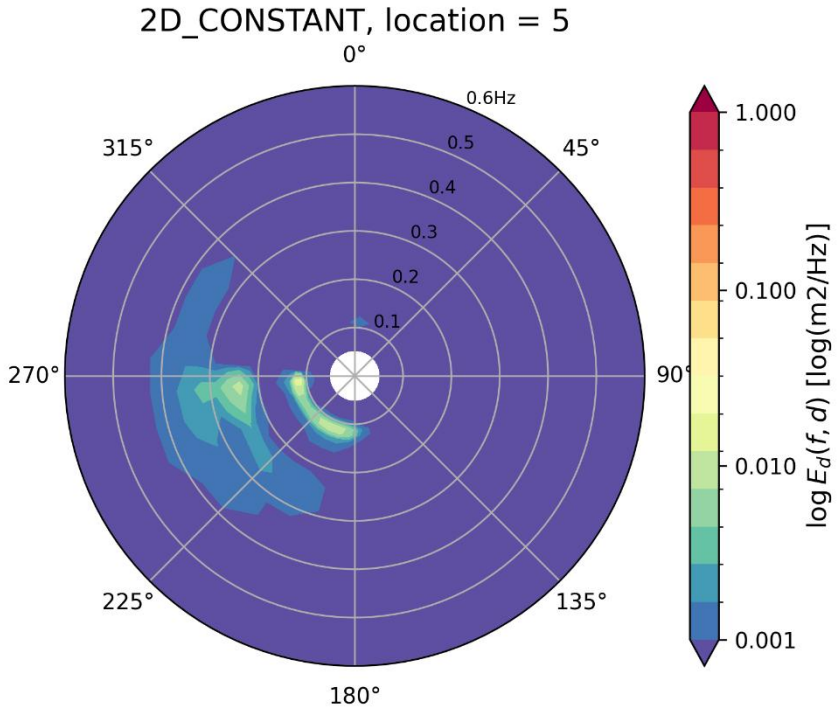
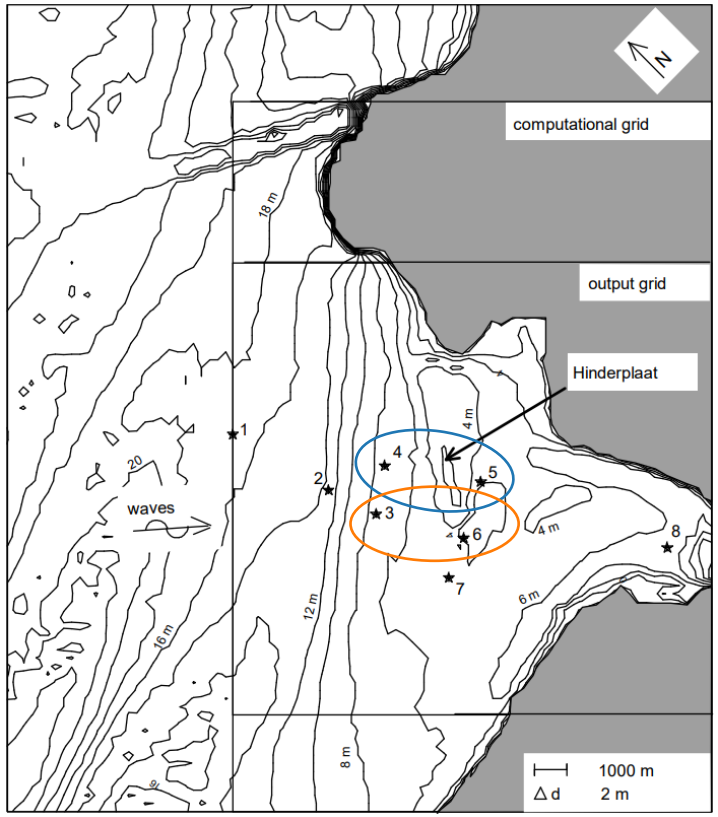
Current performance of breaking formulations

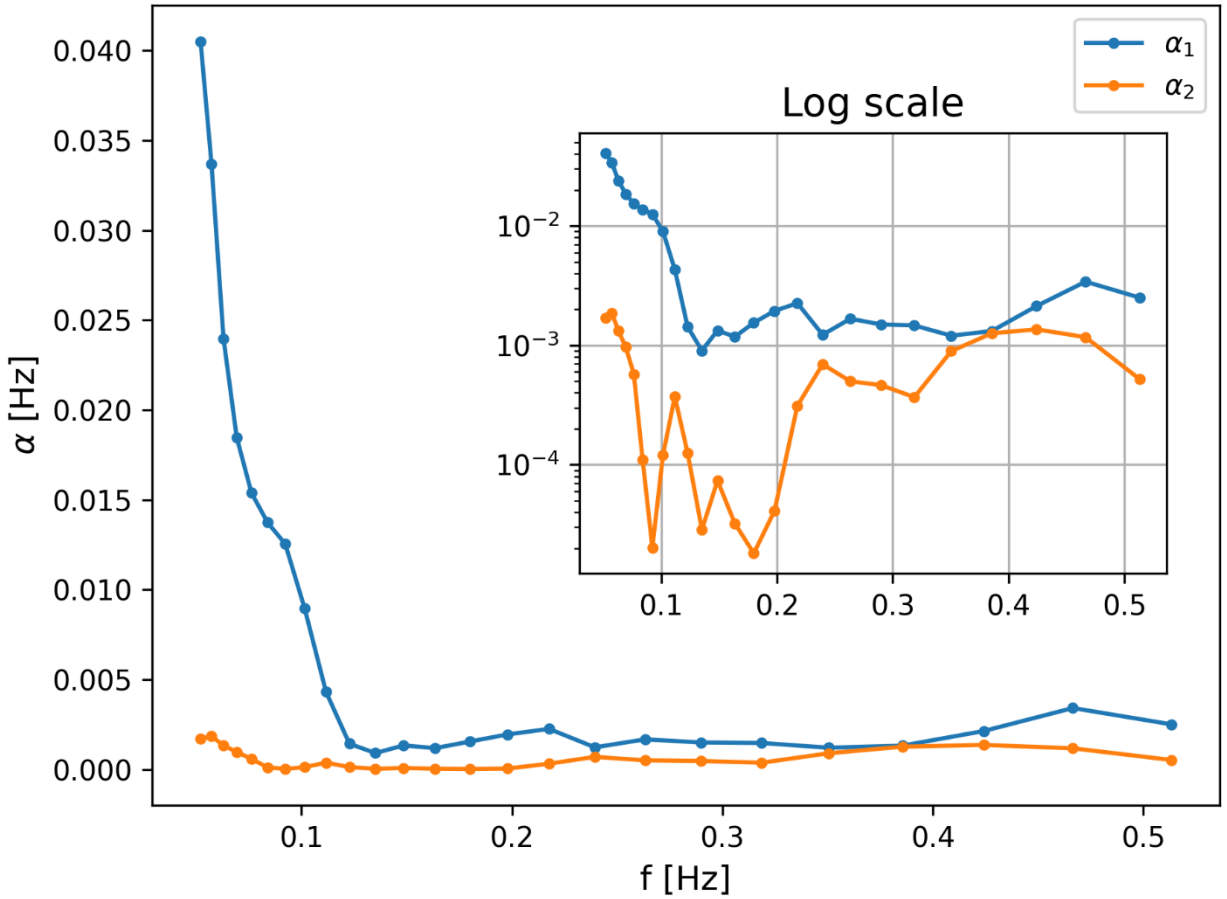




- Indications of frequency dependent dissipation

(New) Results





- Frequency dependence likely for α_1, but not in α_2… How can we be sure?

Statistical testing: Kendall's tau coefficient method

- QUESTION: Frequency dependence likely for α_1, but not clear for α_2… How can we be more sure?
- SOLUTION: Perform a statistical test, using method by (Kendall, 1938)

- H_0: there exists no dependence of the dissipation coefficient on frequency;
- H_a: there exists a dependence of the dissipation coefficient on frequency.

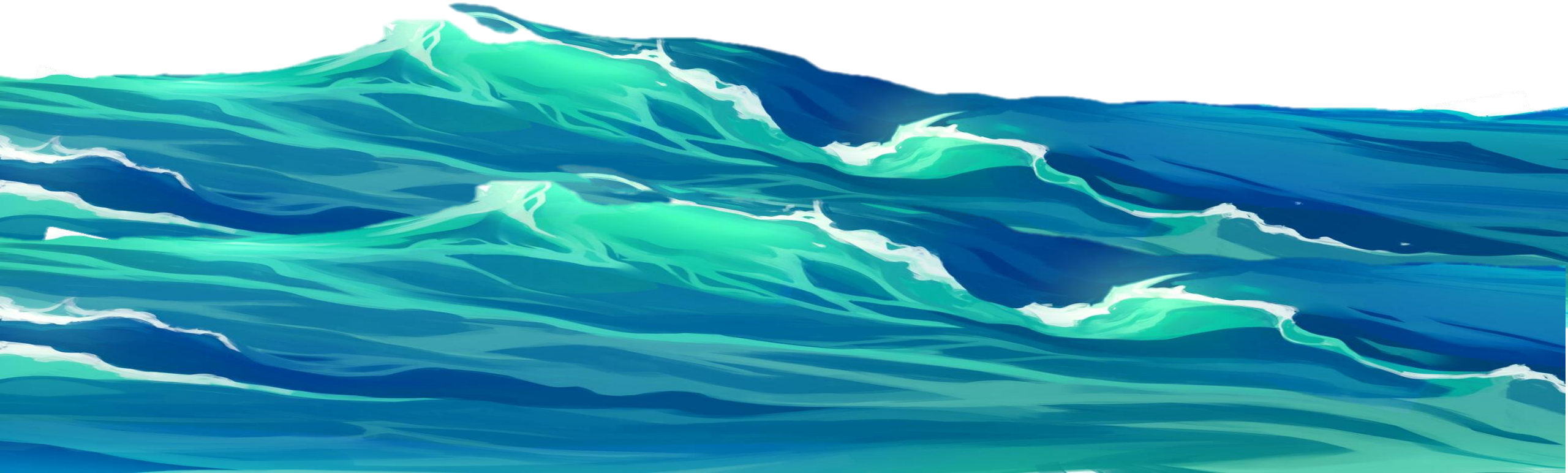
Why Kendall?
- Ordinal (rank-based): applicable to non-linear relations
- Resulting test statistic ('Kendall's tau') approx. ~ N(0,1)

Doing the maths…

α_1 : reject H_0	→	frequency dependence
α_2 : do not reject H_0	→	no frequency dependence

Summary

- QUESTION : frequency dependence in surf zone dissipation?
- CURRENT SITUATION : *not* included in breaker models
- METHOD : simulations with SWAN + observations from Hinderplaat >>> dissipation coefficient α
- RESULTS : statistically significant frequency dependence in 1 of 2 dissipation coefficients

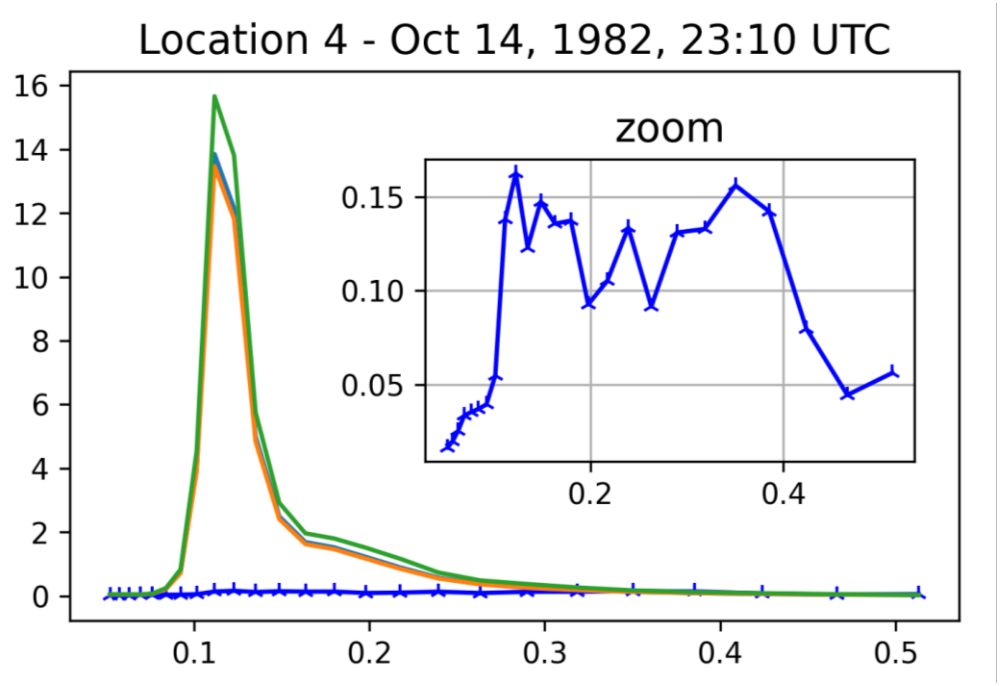


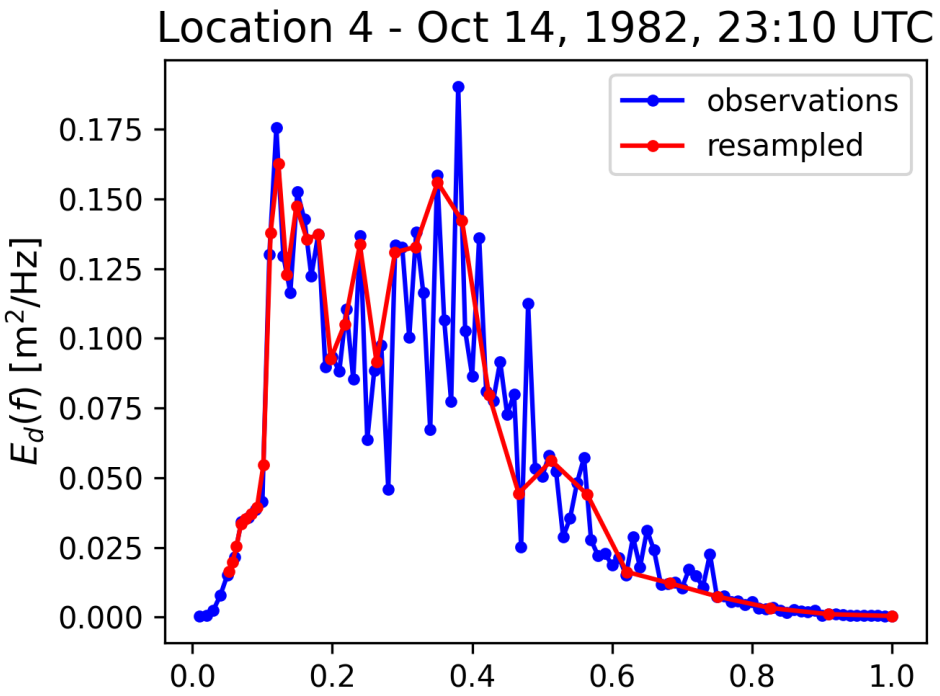
The big caveat

- What is going on at location 4?

$$\alpha_1 = \frac{S_{calc,5}^{nl3,fr} - S_{meas,5}}{2\Delta x S_{meas,4}}$$

- Artefact of data analysis? Doesn't look like it





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Conclusions & recommendations

- Not possible to reliably attribute observed frequency dependence to a physical process
- Instead, recommendations:
  1. More test cases (not easy to arrange short term);
  2. Better calibration of model parameters;
  3. More variety in parametrizations for nonlinear triad interactions (De Wit, 2022)

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Thank you for your attention

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