





Numerical Study of Nonlinear Wave Groups In Shallow Water

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- Investigating waves numerically in shallow waters
- Most of the studies are done for no linear effects on deep water
- In addition, deep water consist of more research due to its readured application in offshore works
- Shallow water is rarely researched
- Non-linearity effects is where we include higher order of waves and combine them into a single waves



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 One study bKatsardand Swan (2011) highlight the difference of dee and shallow water

- Waves of water at deep water and shallow water provide different results and patterns
- In deep water, waves have a big elevation at one point, while shallow water have more larger waves throughout
- This difference are due to the higher order wave notinearities



- Deep Water: Energy are transferred from peak to higher frequencies
- Shallow WateEngergyfrom low and high frequencies transferred to the peak
- Caused by higher order effects



- All the research in the past have been mostly 2 dimensional, with wave energy propagating in one direction
- No studies that was found that go in depth to multiple propagating wave in different directions, at shallow water, through nohnearities wave
- To accurately simulate the record conditions, the 3 points are needed
- Spectrum defines the distribution of energy with frequency





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PROBLEM STATEMENT



- Lack of research on shoutested waves in shallow waters
- Lack of research on multiple wave components at shallow water
- Directionally spread spectrum, non linear effects in shallow water does not exist yet



MAIN OBJECTIVE



- To quantify the effects of higher order non-linearities on crest elevations in directional sea states when compared to uni-directional sea states in shallow water
- To quantify the higher order effects in directional sea states between shallow and deep water



SCOPE OF WORK

- Research spectrum to be limited to Jonswappectrum
- Breaking waves would not be considered



LITERATURE REVIEW

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- Category 1: Articles that focusses on wave statistics, short term statistics on wave height and crest height for ndinear effects
- These articles are useful to determine the wave conditions in a simulation in order to mimic the similar conditions recorded in the real-world
- These articles provides us with the required statistics to mimic the real shallow water conditions

Cited Articles

(Karmpadakis et al., 2020, Katsardi and Swan, 2011, Schubert et al., 2020, Wu et al., 2016)

LITERATURE REVIEW

- Category 2: Articles that highlights the importance of modelling of ndinear waves
- A study done bChatziioannouKatsardi andMistakidis(2015) highlights the importance of nonlinear wave modelling
- Discrepancies up to 30% in predicted loads if nonlinear modelling is not used
- This highlights the importance of Norear wave modelling



LITERATURE REVIEW

- Category 3: Articles that highlights-non linear evolution of waves groups in shallow water in terms of 2 dimensional and 3 dimensional
- For 3 dimensional, only 1 article are found and it is only limited to 3 components
- However, our main goal for this research is to include more components that incorporate all gbnswap'spectrum
- Most of these articles focusses on 2 dimensional waves, with only a few components
- Thus our research would be focussing on Jonswappectrum, for waves propagating in all direction, at shallow water

Cited Articles

(Katsardi and Swan, 2011, Karmpadakis and Swan, 2020, Liu and Xie, 2019, Vyzikas et al., 2018, Xu et al., 2012)



METHODOLOGY

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- Simulation of directional and Uni directional with different sea state parameters
- To compare and analyse between the directional and Undirectional
- Model would be referred to Bateman, Swan & Taylor (2001, 2003)
  - Model can be utilize to simulate fully nonlinear waves
  - Highly Accurate
  - Efficient





#### **FLOW CHART**



#### GANTT CHART

|                                                        | FYP 1 (weeks) |   |   |   |    |   |   |   |   |    |    |    |
|--------------------------------------------------------|---------------|---|---|---|----|---|---|---|---|----|----|----|
|                                                        | 1             | 2 | 3 | 4 | 5  | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| Study on Hydrodynamics.<br>Regular and Irregular waves |               |   |   |   |    |   |   |   |   |    |    |    |
| Introduction to MATLAB                                 |               |   |   |   |    |   |   |   |   |    |    |    |
| Literature Review                                      |               |   |   |   |    |   |   |   |   |    |    |    |
| Scope, Objective, Problem<br>Statement                 | 1             |   |   |   |    |   |   |   |   |    |    |    |
| Developing Methodology                                 |               |   |   |   |    |   |   |   |   |    |    |    |
| Proposal Defense                                       |               |   |   |   |    |   |   |   |   |    |    |    |
| Interim Report                                         |               |   |   |   |    |   |   |   |   |    |    |    |
|                                                        |               |   |   |   | 18 |   |   |   |   |    |    |    |

#### GANTT CHART

|                                                               | FYP 2 (weeks) |   |   |   |    |   |   |   |   |    |    |    |
|---------------------------------------------------------------|---------------|---|---|---|----|---|---|---|---|----|----|----|
|                                                               | 1             | 2 | 3 | 4 | 5  | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| Validate BST Model                                            |               |   |   |   |    |   |   |   |   |    |    |    |
| Generate Wave Groups in 2D o<br>3D                            | &             |   |   |   |    |   |   |   |   |    |    |    |
| AnalysisOf 3D and 2D shallow<br>water                         |               |   |   |   |    |   |   |   |   |    |    |    |
| Analysisof 3D deep water and shallow water                    |               |   |   |   |    |   |   |   |   |    |    |    |
| Fourier Analysis to understand<br>non-linear wave interaction |               |   |   |   |    |   |   |   |   |    |    |    |
| Reporting and Evaluation                                      |               |   |   |   |    |   |   |   |   |    |    |    |
|                                                               |               | • |   |   |    |   |   |   |   | •  |    |    |
|                                                               |               |   |   |   | 19 |   |   |   |   |    |    |    |



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#### VALIDATION

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- To validate produced figures against Katsaldand Swan (2011)
- To prove the accuracy of our generated model against a published and widely known paper







#### Validation of Energy Spectrum

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#### NONLINEAR WAVES

- Surface elevation increase in deep water and decrease in shallow water
- Concentrated wave in deep water and spread waves in shallow water



#### NONLINEAR WAVES

- In deep water, waves becoming concentrated forming a high peak elevation
- In shallow water, waves remainsspreaded throughout



#### Amplitude Spectrum

#### In deep water

 energy were transferred towards higher frequencies over time, decreasing peak amplitude

Shallow water consist of 2 stage effects.

- Stage 1: energy transferred towards peak, lower and higher frequencies
- Stage 2: Energy transferred away from the peak



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### **Spectral Bandwidth**

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In deep water

- Energy gradually become spread ur the peak
- In shallow water
  - Energy starts aspreaded began to be concentrated, and at t = 82s, energy became spread.



#### **Directional Waves**

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#### In directional seas

- Peak surface elevation were higher than the starting elevation of 5m. The opposite effect in ni-directional seas
- Directional waters remain focussed comparison touni-directional. Very similar to deep water





#### **Evolutions of Waves**





#### **Evolution of Amplitude Spectrum**

- Energy were transferred towards higher and lower frequencies overtime and reaches its peak at t = 85.209s
- At maximum surface elevation, energy transferred from x axis and y axis towards the peak, high and low frequencies. This meant that directional waves play a big role
- A similar reaction towardsuai-directional deep water. Thus, the two stage effects observed inuni-direction disappears.





#### CONCLUSION

- The research is to compare betweendirectional and directional wave conditions in shallow water u non-linear waves.
- Surface elevation higher than starting elevation in directional waves
- Two stage effects imi-directional waves were not seen in directional waves
- Directional shallow water acts more similarly towa uni-directional deep water waves
- Recommendations: To research on more angles, real world studies, to do on different spectrums



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Any questions?

#### **ETA ODD in Directional Waves**

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