

# **Modelling wave-tide interactions at a wave farm in the Southwest of England**

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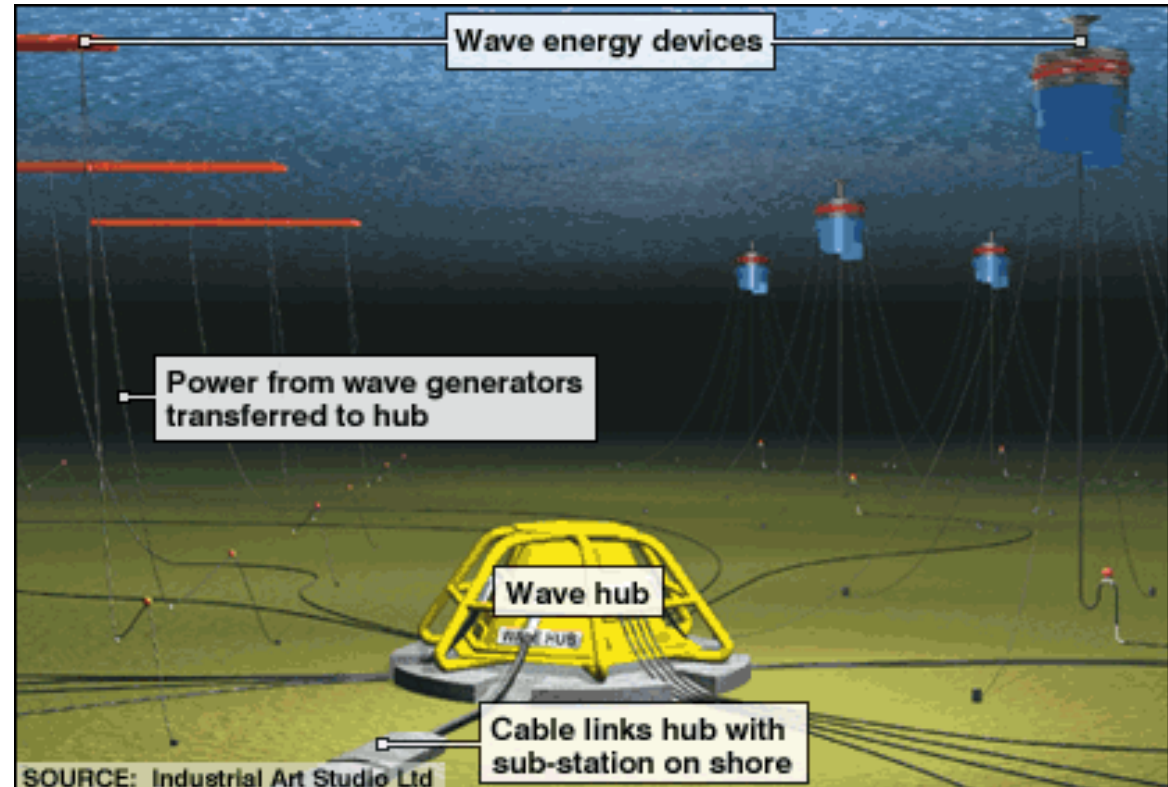
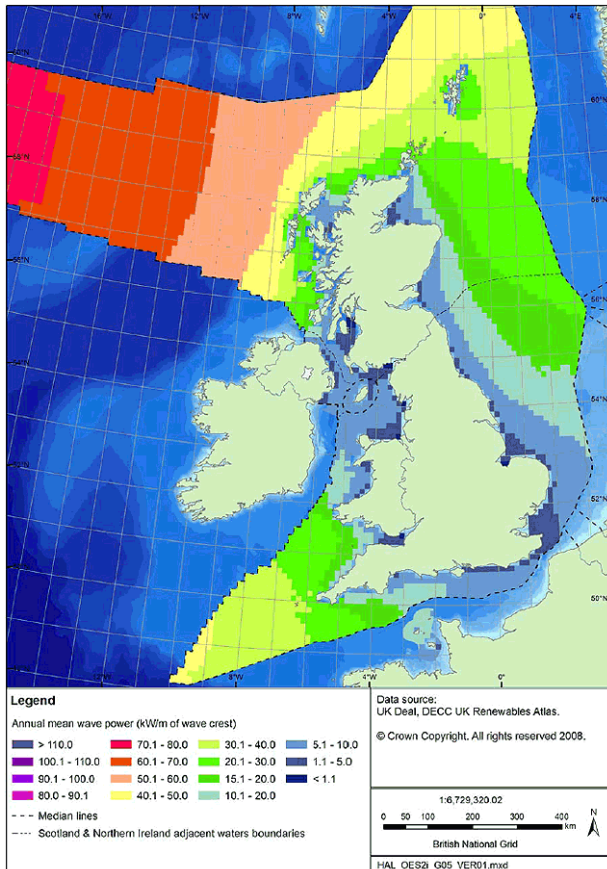
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- ▶ Introduction
- ▶ Methodology
- ▶ Modelling System
- ▶ Results
- ▶ Conclusions
- ▶ Future Work



# Introduction

- ▶ UK Wave Energy
- ▶ Wave Hub

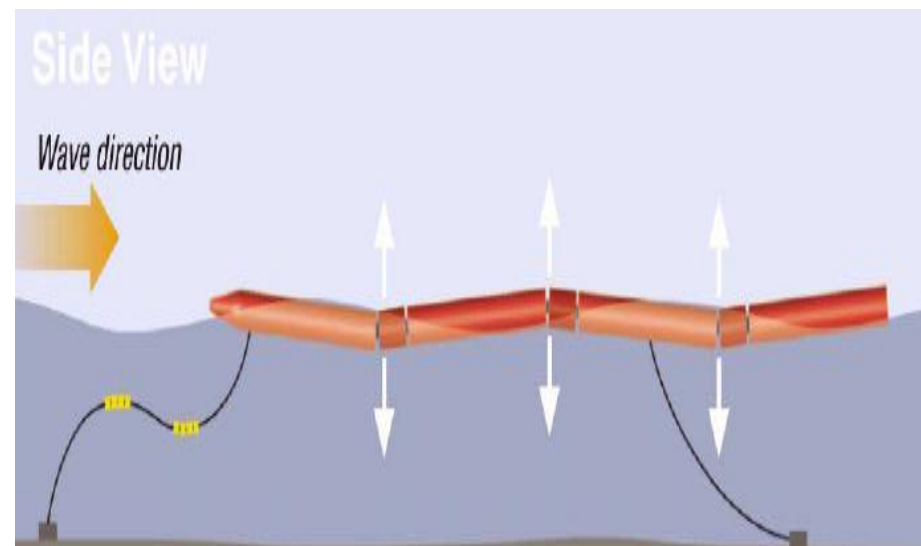


## Examples of wave energy devices



# The Wave Hub Project

- ▶ Funded by SWDRA/EU
- ▶ To quantify resources characterisation
- ▶ To study the response of wave energy converters
- ▶ To understand the interaction between waves and WEDs
- ▶ To predict the impacts to adjacent coastlines and beaches
- ▶ To assess impacts of climate change



# Motivation

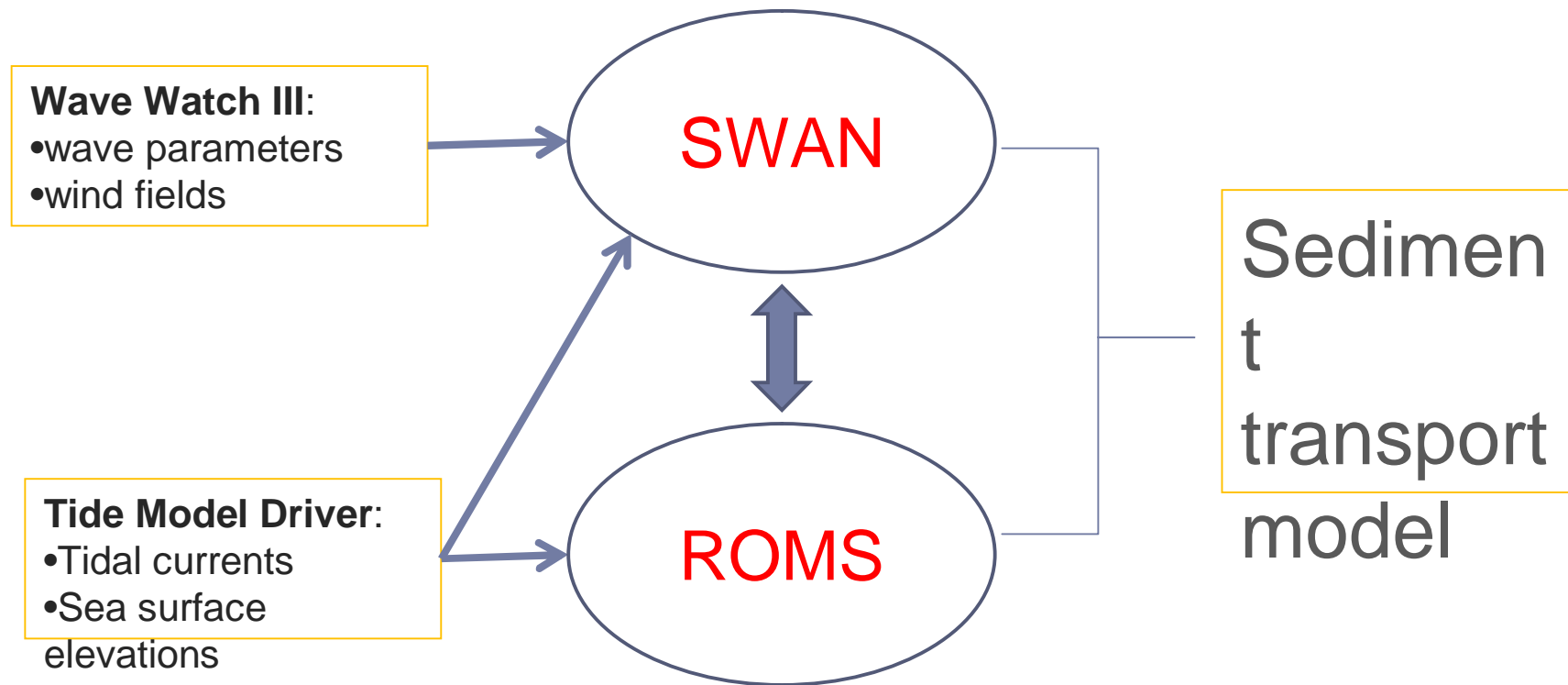
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- ▶ Recent studies at the Wave Hub site suggest that wave induced currents are important in controlling sediment movement.
- ▶ Lack of studies and calibration of wave and circulation models at the Wave Hub site.
- ▶ Better understanding of waves, tides and sediment transport, are crucial to the wave resource characterization and environmental impact assessment at the Wave Hub site.



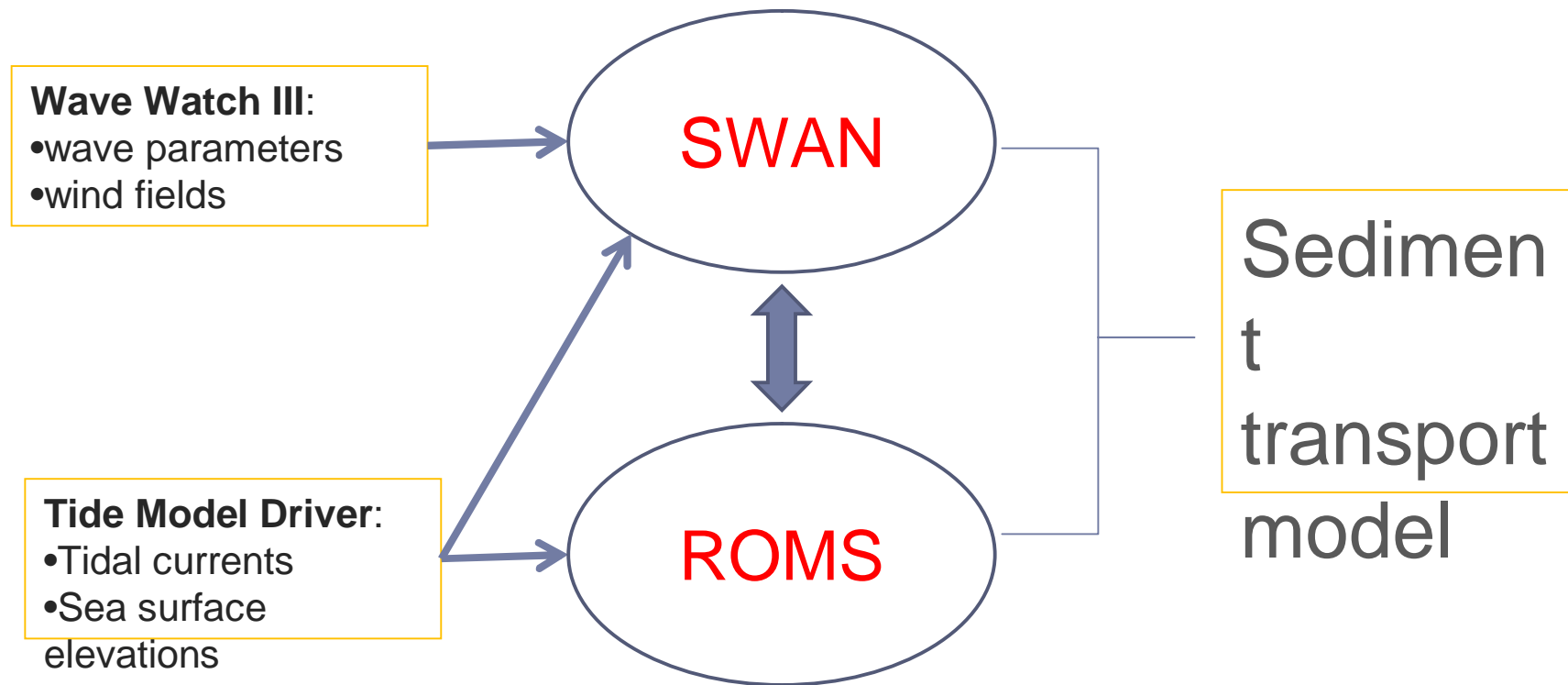
# Methodology

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# Methodology

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# Tide Model Driver

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## OTPS

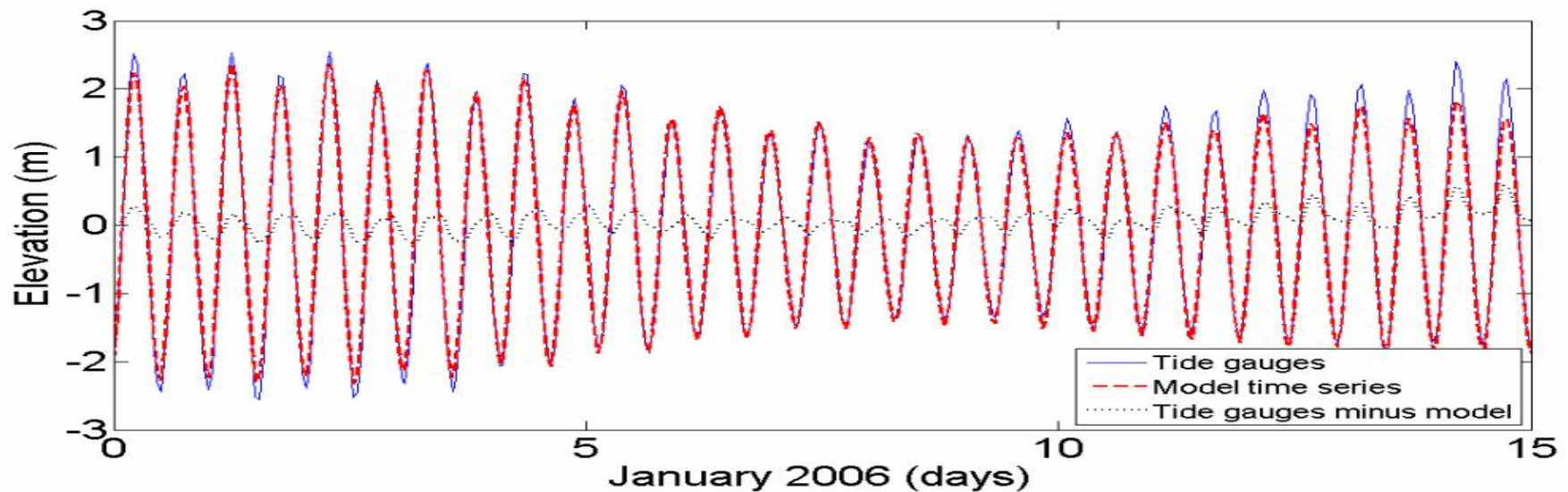
Ocean tidal prediction software based on the TOPEX/Poseidon altimeter data

## TMD

The Tide Model Driver a tidal prediction software

## Tidal currents/Elevations

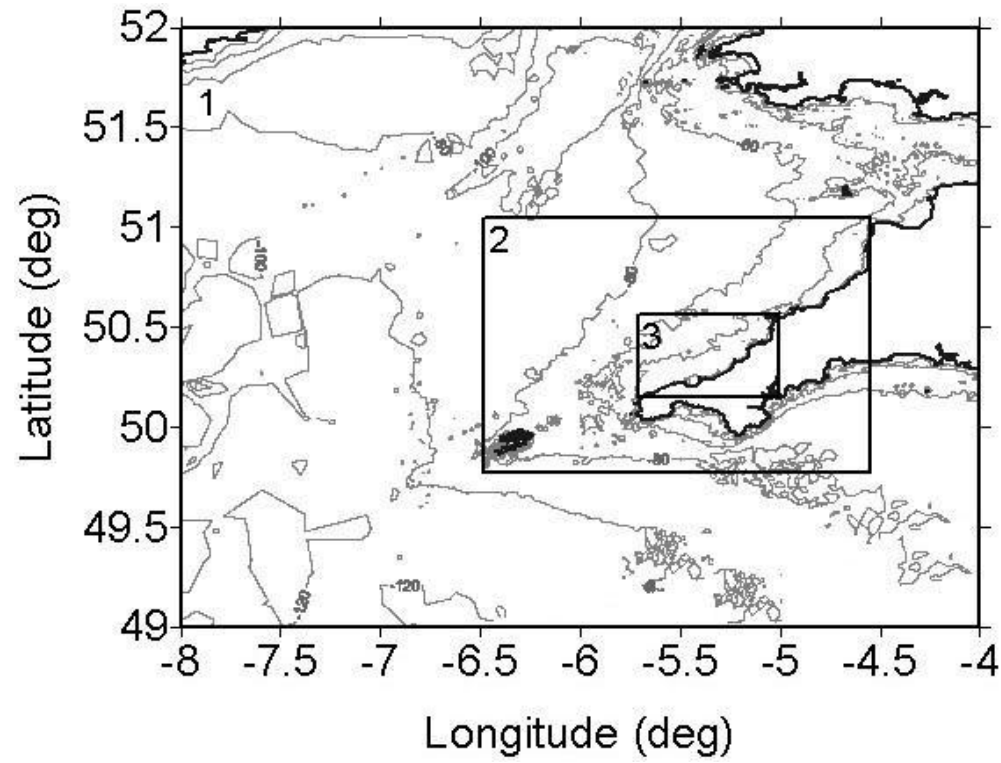
(M<sub>2</sub>, S<sub>2</sub>, N<sub>2</sub>, K<sub>2</sub>, K<sub>1</sub>, O<sub>1</sub>, P<sub>1</sub>, Q<sub>1</sub>, M<sub>4</sub>, MS<sub>4</sub>, MN<sub>4</sub>)





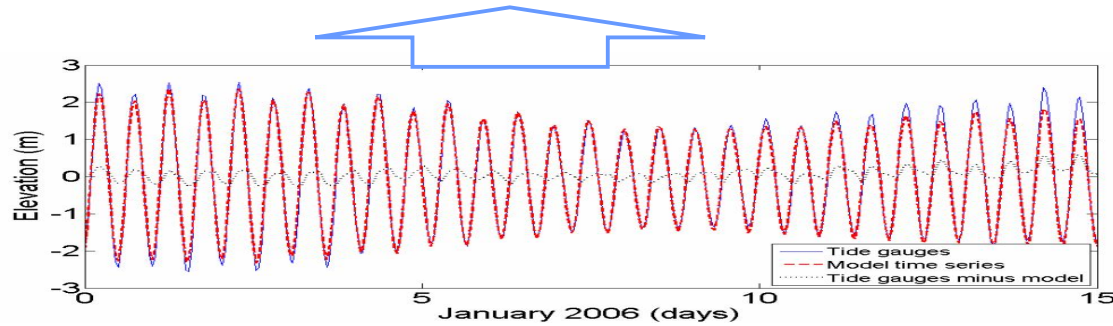
# Nested Wave and Tide Models

Wave Watch III  
(wave  
parameters and  
wind fields)



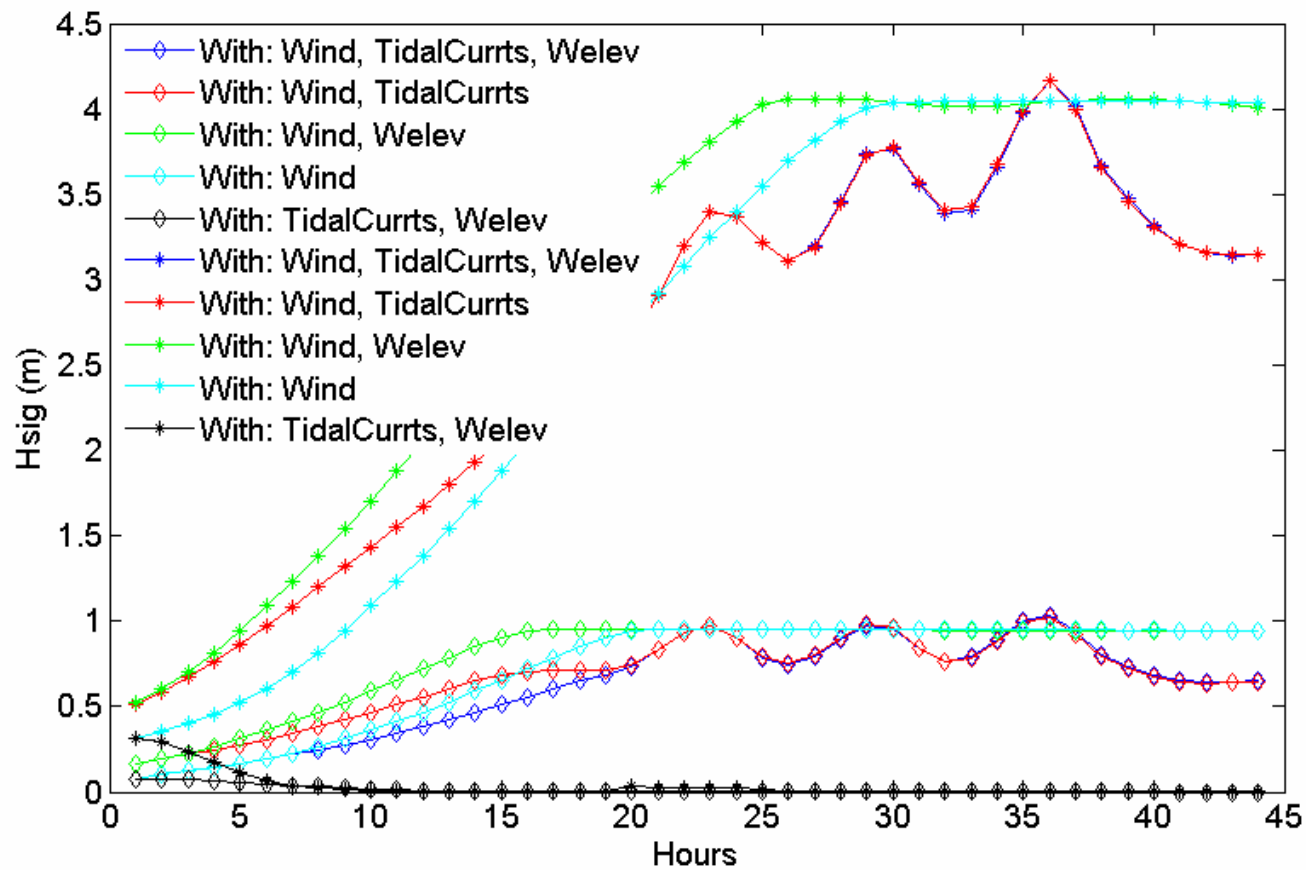
Nested grids  
for SWAN and  
ROMS  
models,;  
(1)coarse  
(2)intermediat  
e  
(3)fine

Tidal currents by the  
Tide Model Driver  
(TMD).



# SWAN Test Cases

- ▶ Waves affected by wind, tidal elevation & tidal

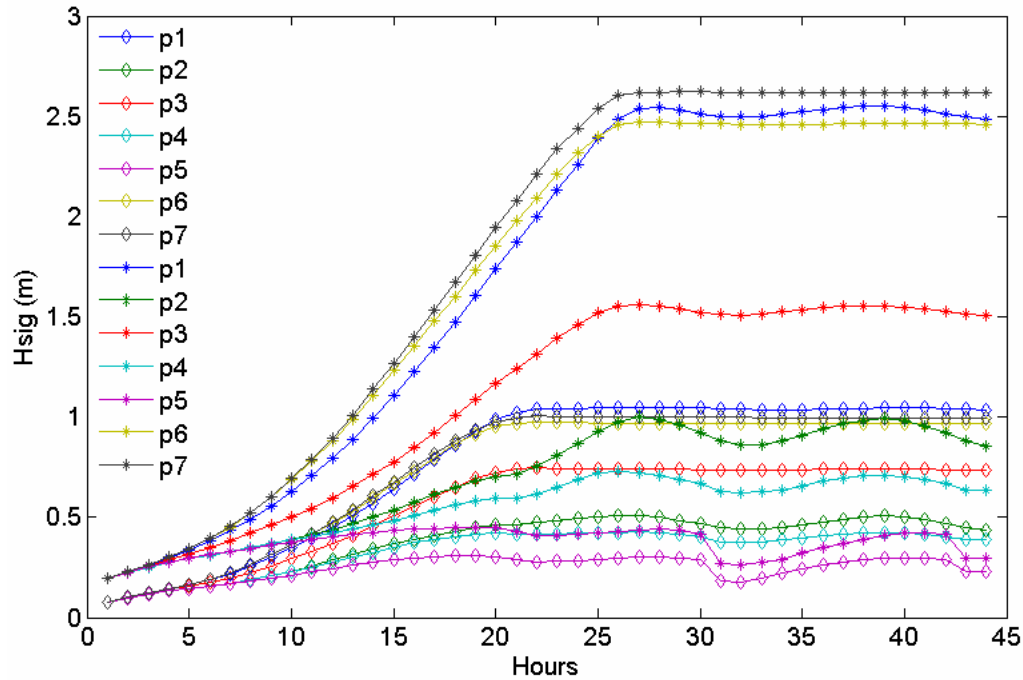
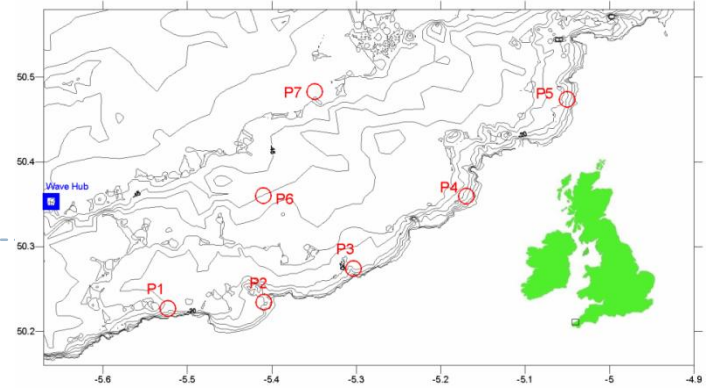


**Extreme**  
Wind 20 m/s,  
Hs = 3.3 m,  
Tm = 11 sec,  
Dir = 200d

**Normal**  
Wind 10 m/s  
Hs = 1.6 m,  
Tm = 5.4 sec,  
dir = 200d.

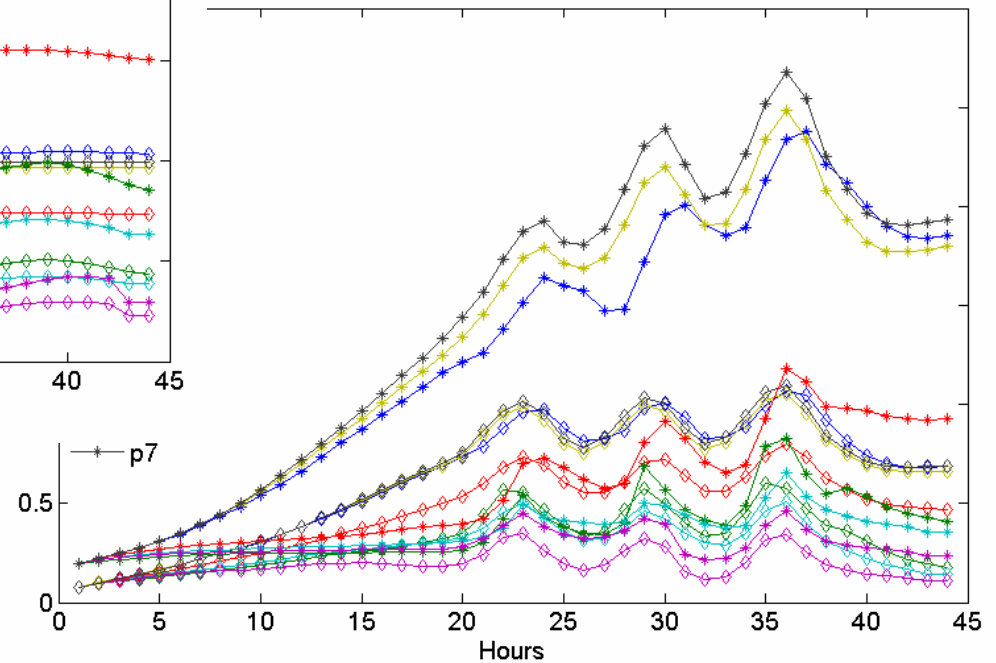
# SWAN Test Cases

## ▶ Waves at Various points at WH



Without tidal currents

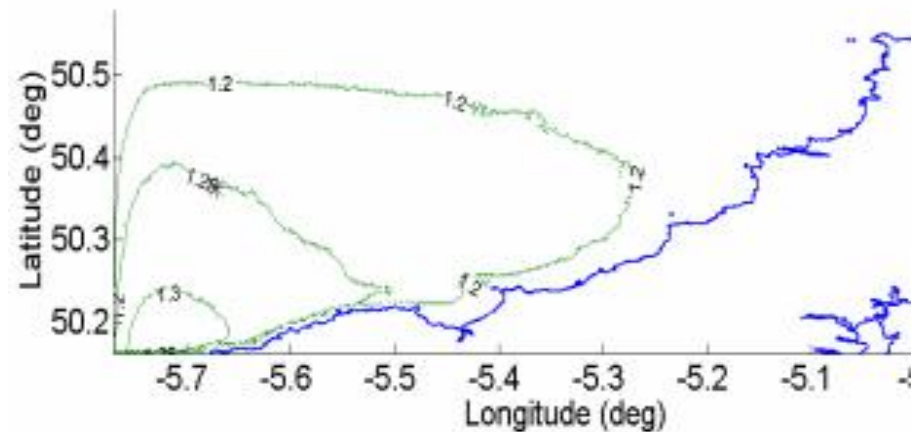
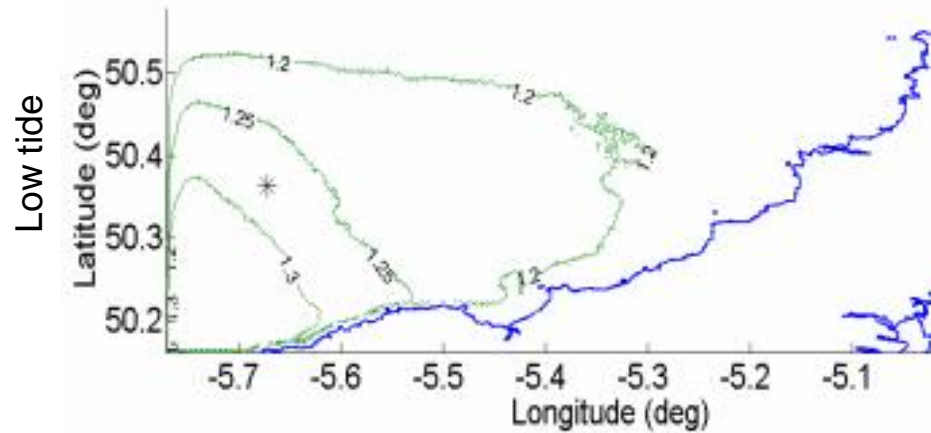
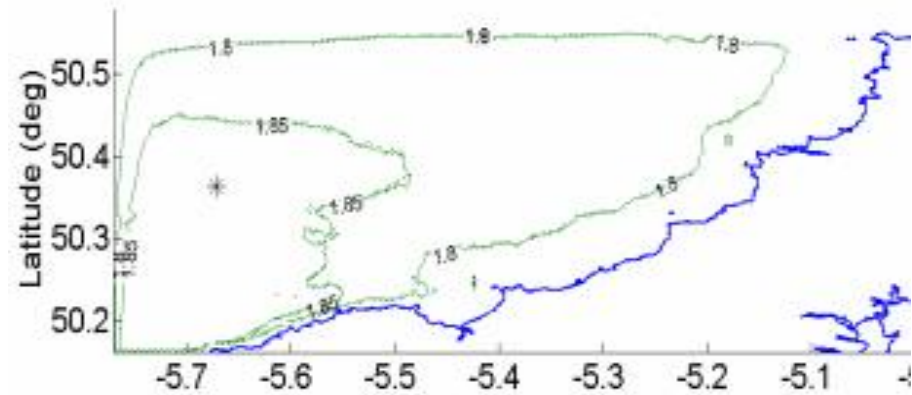
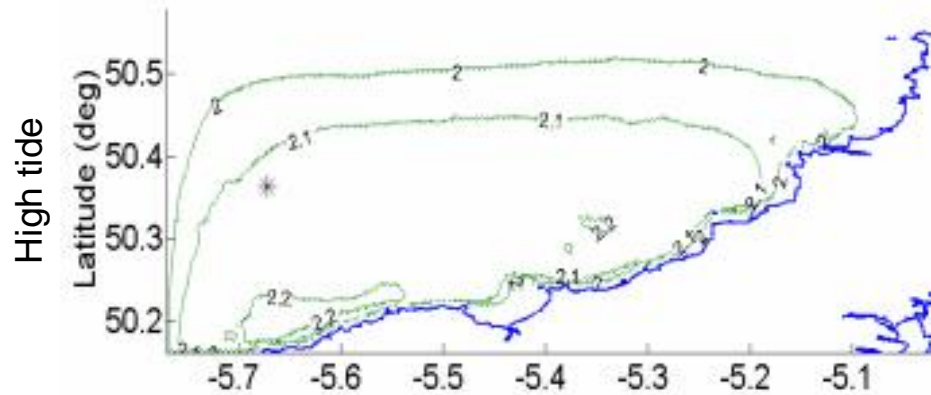
With tidal currents



# Effect of Tidal Currents on Waves

▶ With tidal currents

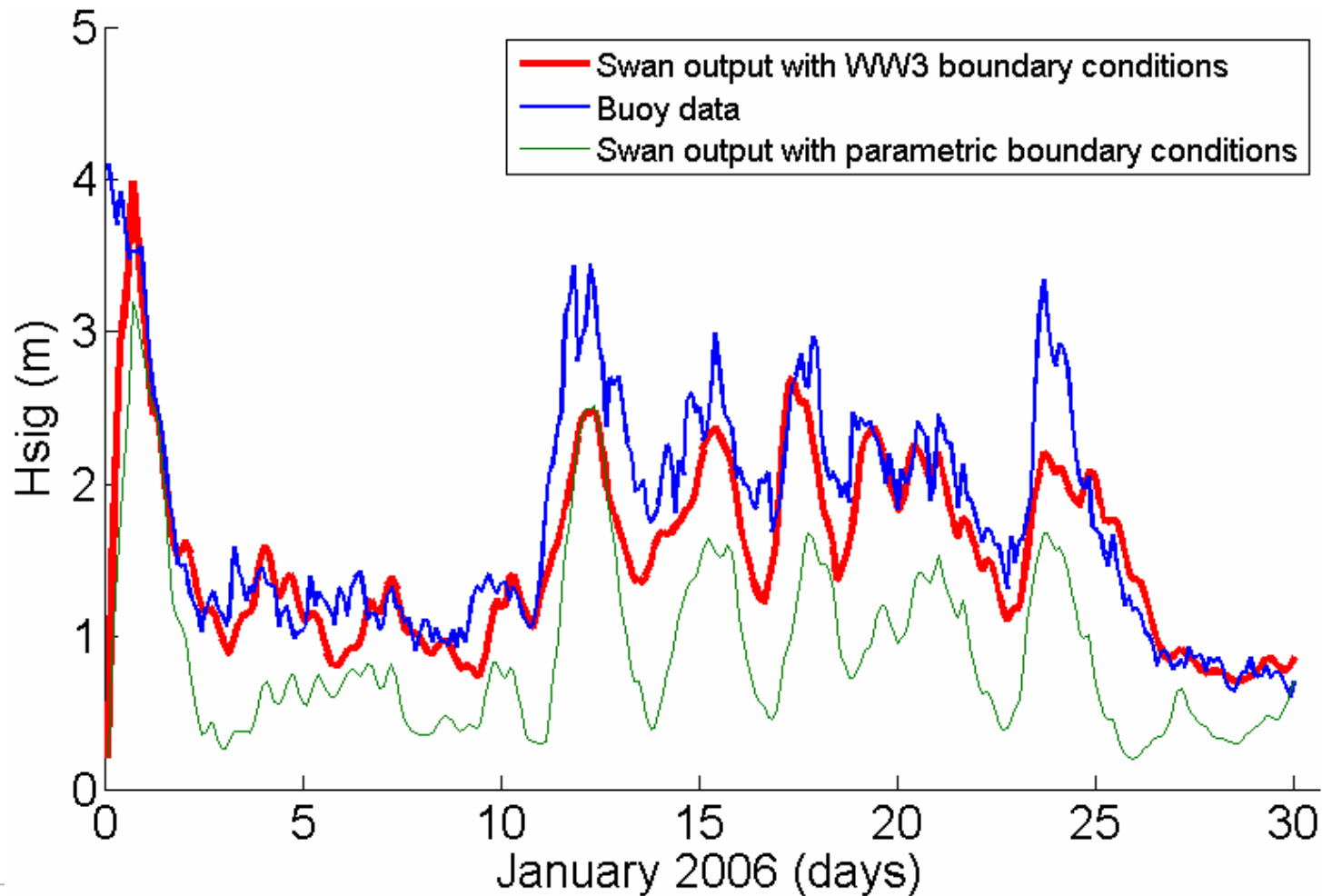
▶ Without tidal currents



# Effect of Boundary Conditions on Waves

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## ► At Wave Hub



# The ROMS model

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## ► Governing Equations

$$\frac{\partial u}{\partial t} + \vec{v} \cdot \nabla u - fv = -\frac{\partial \phi}{\partial x} - \underbrace{\frac{\partial}{\partial z} \left( \overline{u'w'} - \nu \frac{\partial u}{\partial z} \right)}_{\text{Vertical diffusion}} + F_u + D_u$$

Vertical diffusion

### Bottom shear stress

- Bottom Boundary Layer
- Vertical column mixing
- Wave-current interaction
- Sediment transport study

$$\overline{u'w'} = -K_M \frac{\partial u}{\partial z}; \quad \overline{v'w'} = -K_M \frac{\partial v}{\partial z};$$

Reynolds stress

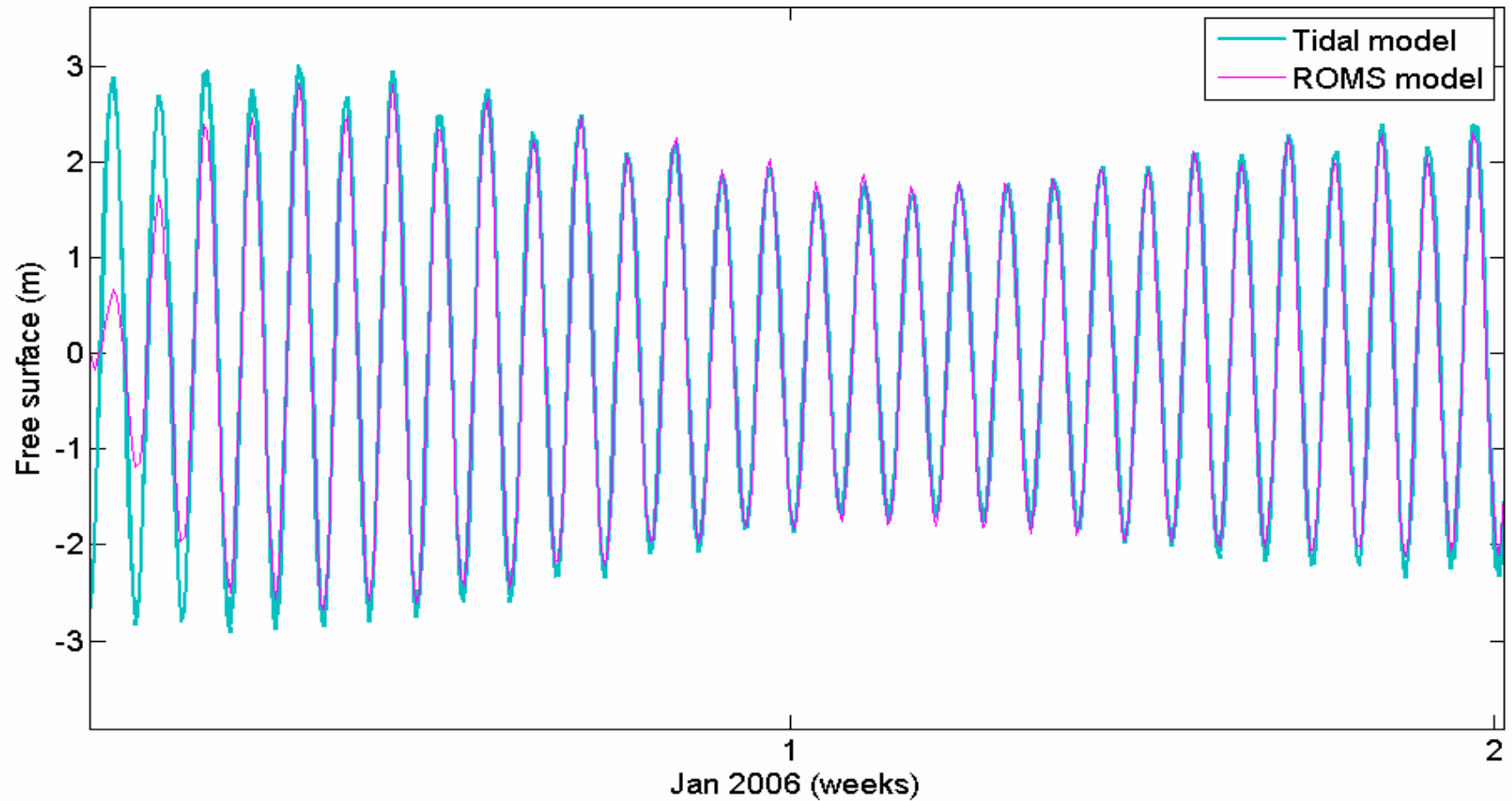
$$K_M \frac{\partial u}{\partial s} = \tau_{bx}, \quad K_M \frac{\partial v}{\partial s} = \tau_{by}$$



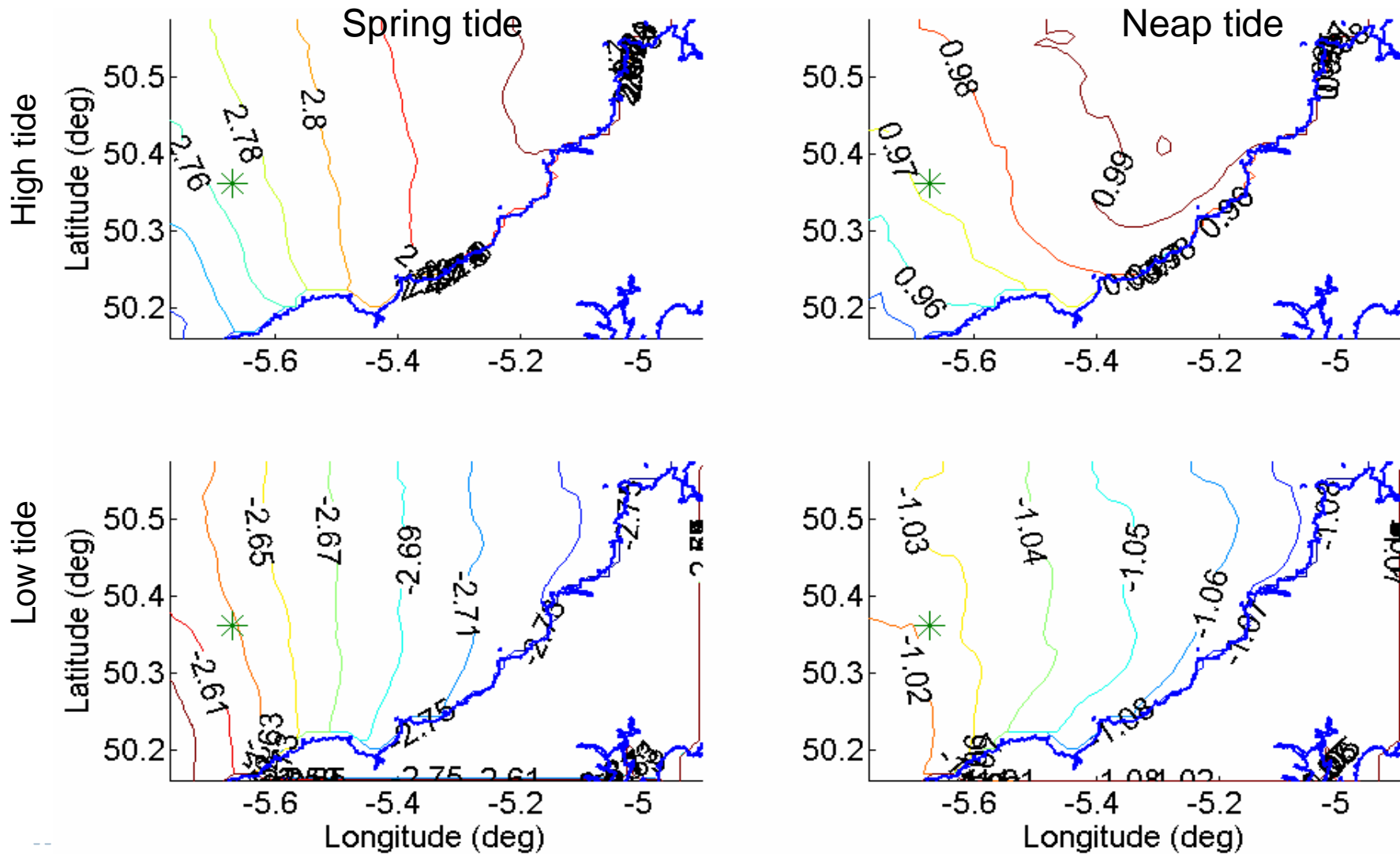
# Predicted Tides by ROMS

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## ► At Wave Hub



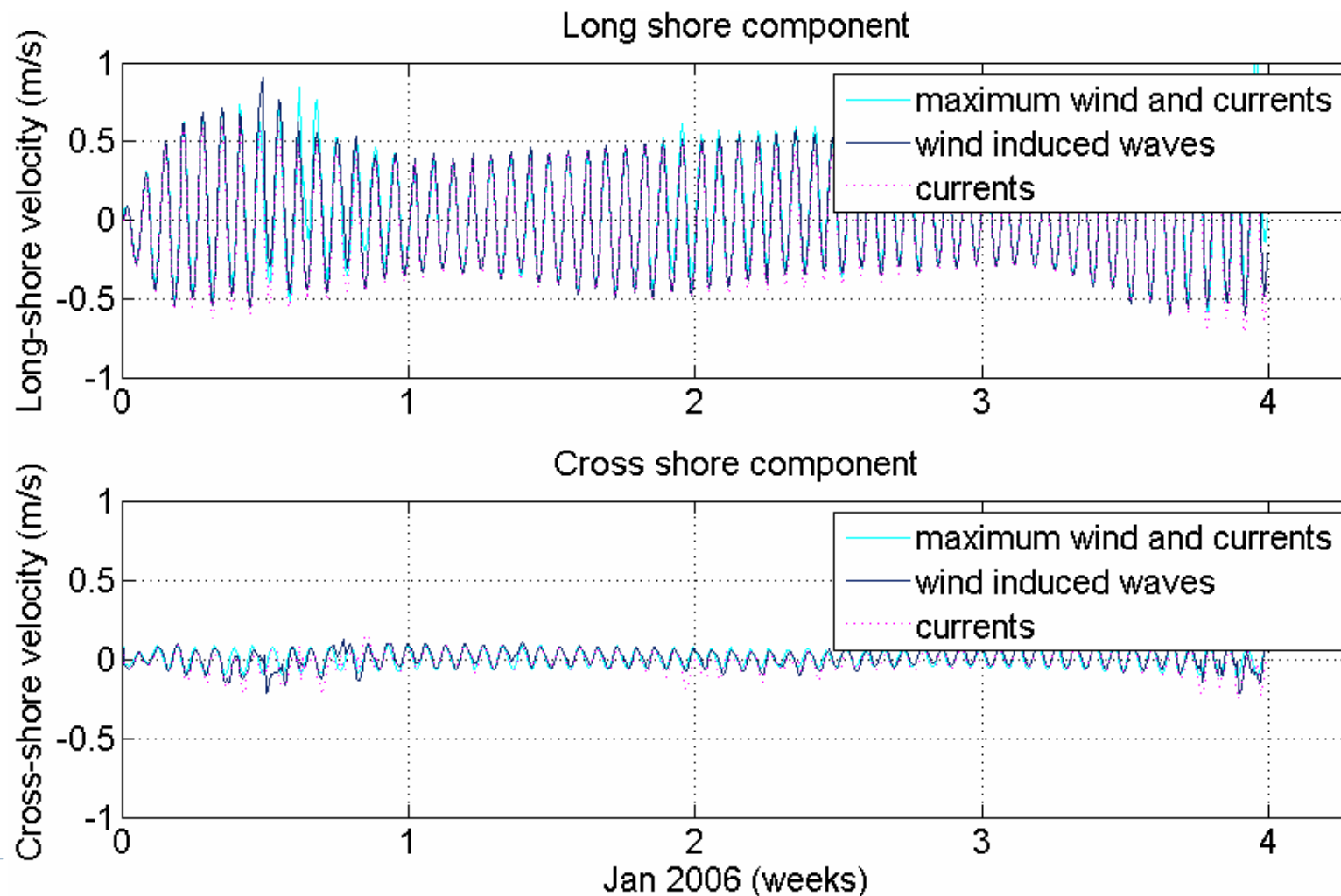
# Predicted Tides by ROMS





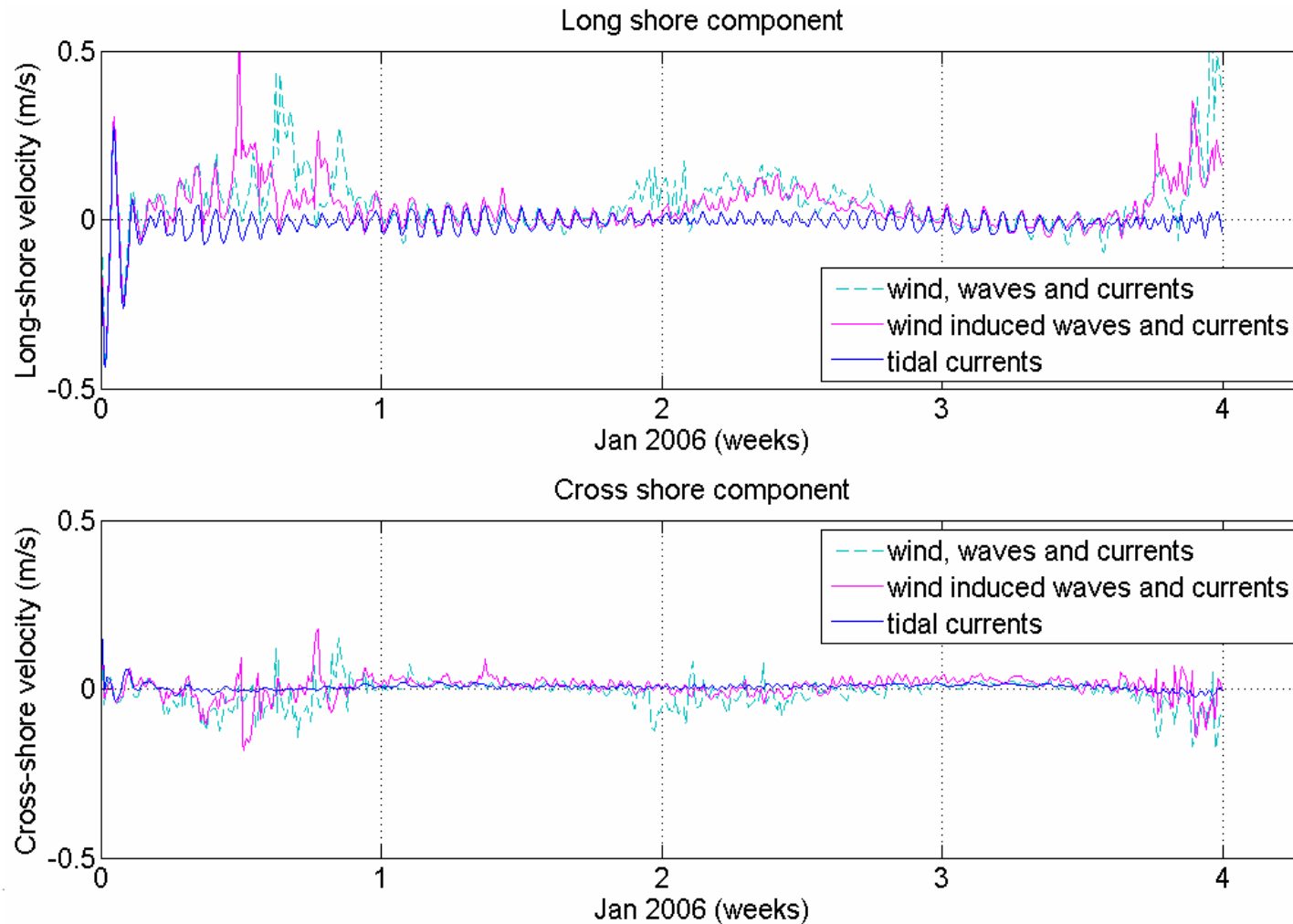
# Effect of Waves on Currents

## ► Re-arrange velocity



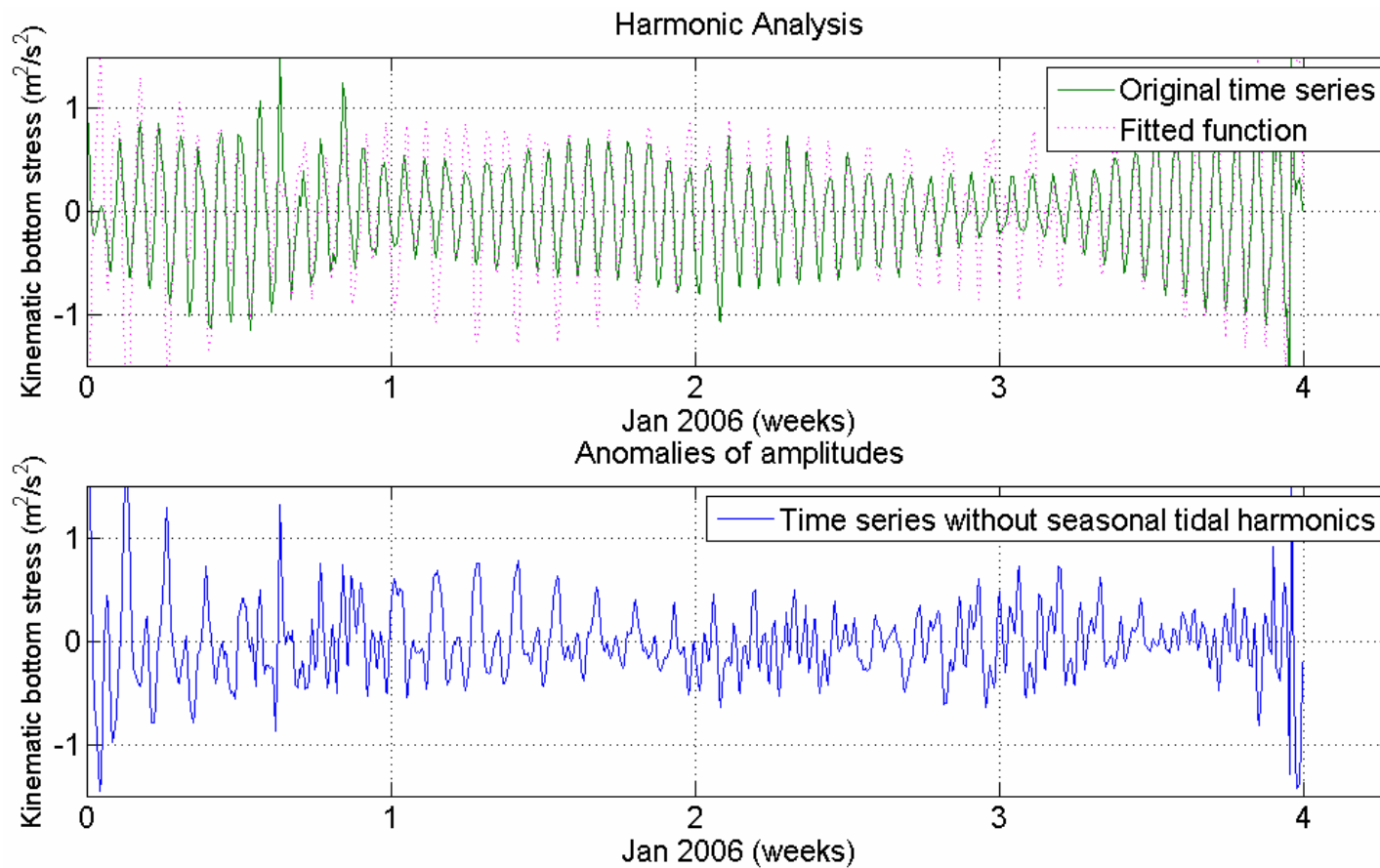
# Effect of Waves on Currents

## ► Velocity Residuals

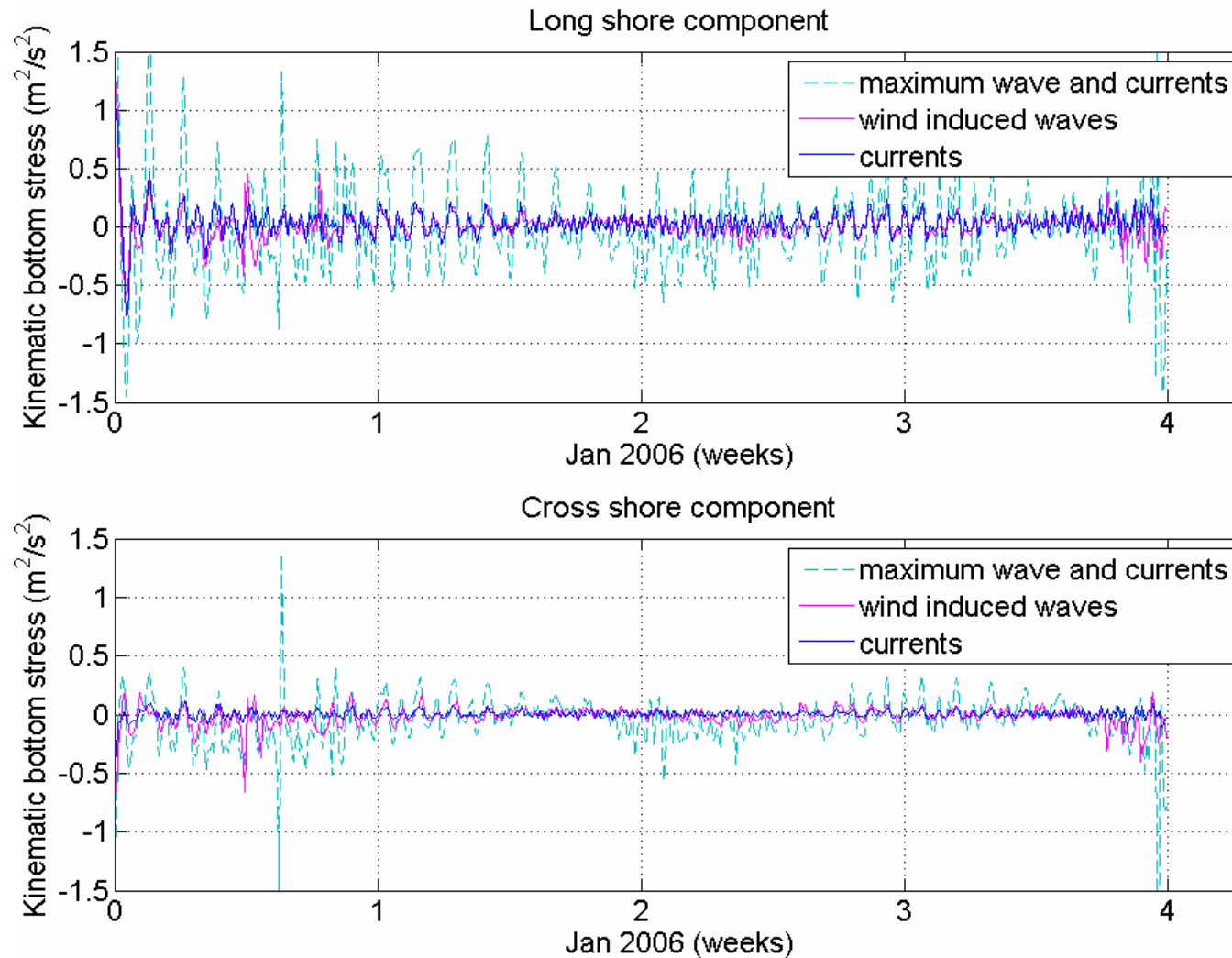


# Effect of Waves on Bottom Stress

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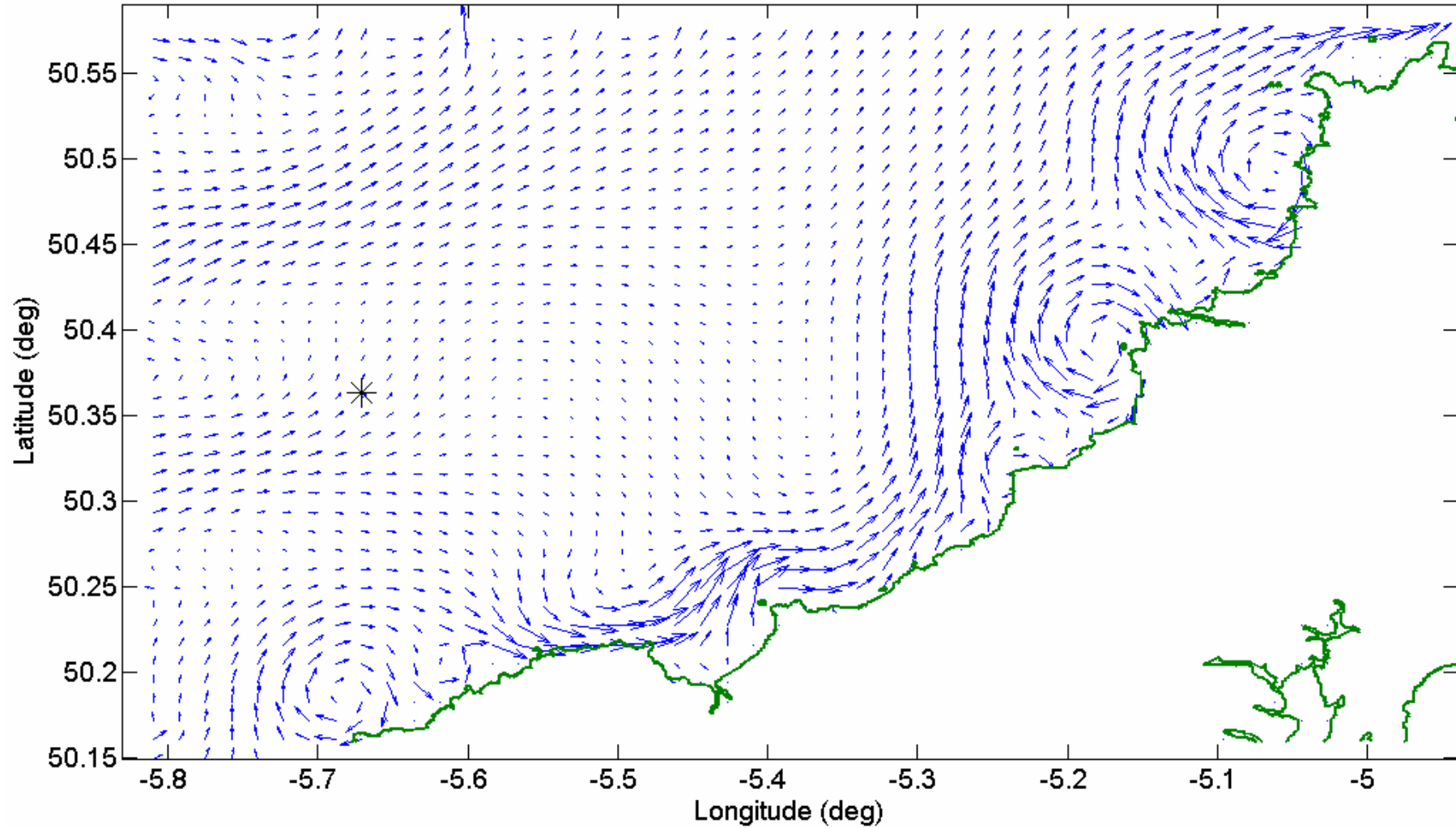


# Effect of Waves on Bottom Stress



# Predicted Currents by ROMS

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# Conclusions

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- ▶ The tidal elevation and tidal currents have a significant effect on the wave height predictions
- ▶ Tidal forcing and wind waves have a significant effect on the bed shear-stress, relevant to sediment transport
- ▶ Waves via radiation stresses have an important effect on the longshore and cross-shore velocity components, particularly during the spring tides
- ▶ Waves can impact on bottom boundary layer and the mixing in the water column
- ▶ Interaction between waves and tides at the Wave Hub site is important when modelling coastal morphology influenced by wave energy devices



# Future work

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- ▶ The incorporation of the two-way wave-tide interaction.
- ▶ Study of wave induced currents through the two-way coupled system.
- ▶ Test cases with non-stationary inputs to the modelling system.
- ▶ Model validations against the wave and current measurements by HF RADAR, ADCP and Directional Waverider buoys during the on-going Wave Hub projects

# Predicted Currents by ROMS

