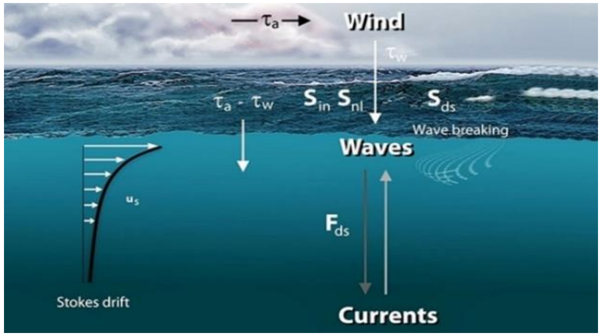
ASSESSING THE ADDED VALUE OF USING A WAVE BOUNDARY LAYER MODEL IN A COUPLED WAVE-ATMOSPHERE MODEL SYSTEM



Anne Wiese [a], Jana Fischereit [b], Xiaoli Guo Larsén [b], Joanna Staneva [a]

[a] Helmholtz-Zentrum Geesthacht, Germany

[b] Department of Wind Energy, Technical University of Denmark, Risø Campus, Roskilde, Denmark

2nd International Workshop on Waves, Storm Surges and Coastal Hazards

Melbourne, 11.11.2019

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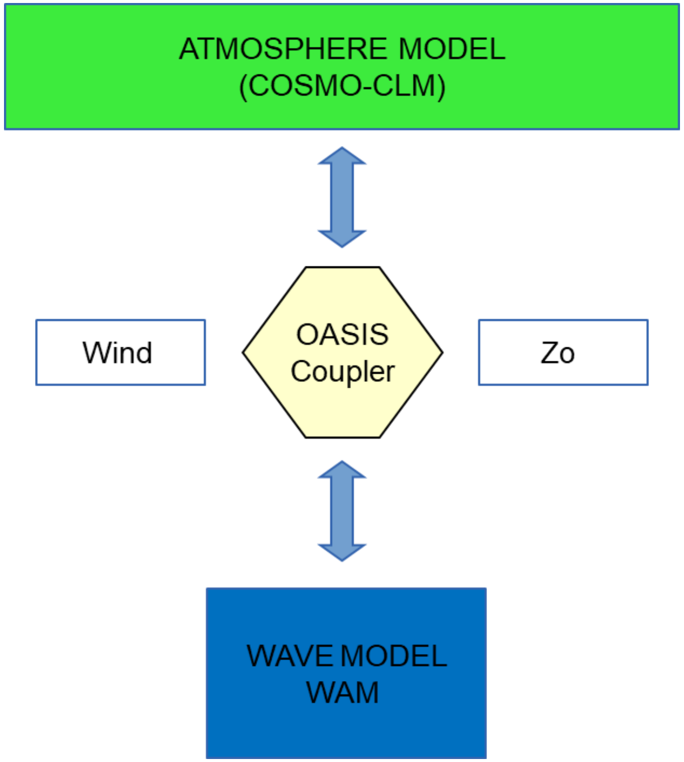
CEASELESS

INTRODUCTION

- Exchange variables for momentum and heat are important in coupled atmosphere- wave-ocean models

- For coupled atmosphere-wave models:
    - Roughness length of the ocean surface needs to depend on sea state and not only on wind



WIND SPEED VERSUS ROUGHNESS LENGTH

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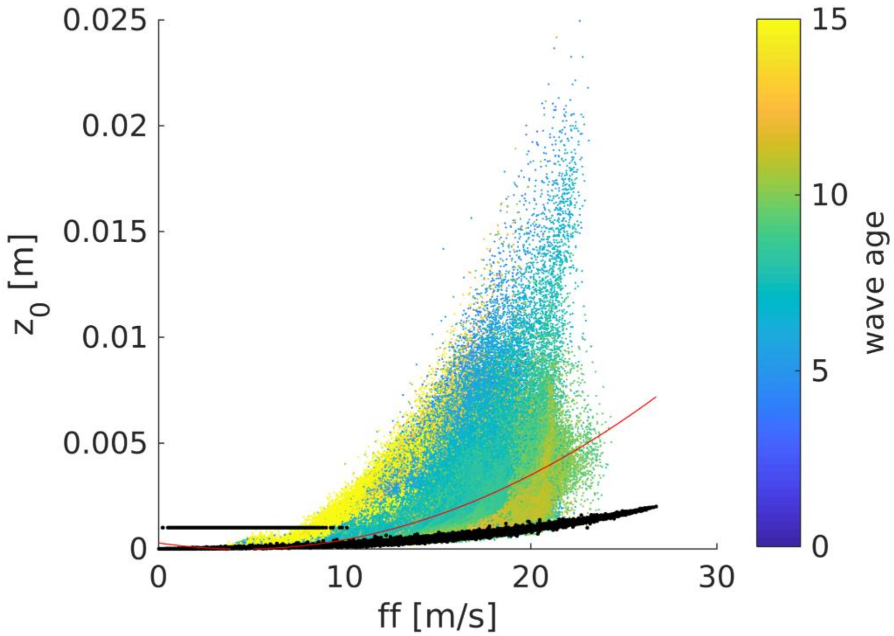

Reference run:
Charnock parameterization:

$$z_0 = \frac{\alpha \tau}{g}$$

→ z_0 wind dependend

Coupled run:

$$z_0 = \frac{\hat{\alpha}\tau}{g} \frac{1}{\sqrt{1-\tau_w/\tau}}$$

→ z_0 wave dependend

α Charnock parameter
$\hat{\alpha}$ constant (= 0.01 in WAM)
τ_w wave induced stressed
(from wave spectrum (Janssen 1991))
τ total stress

MSLP, 10M WIND SPEED, SURFACE ROUGHNESS

13.01.2017 12UTC

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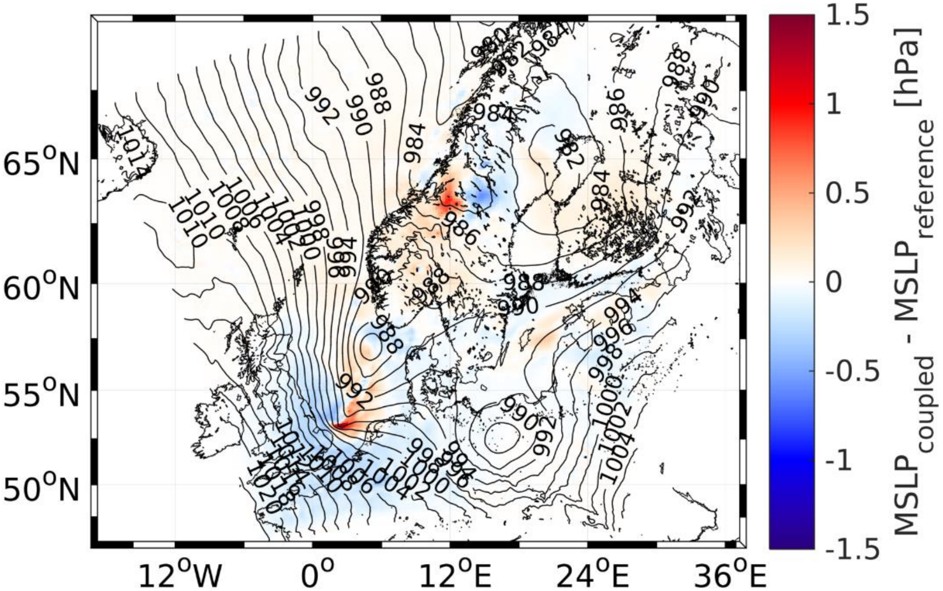

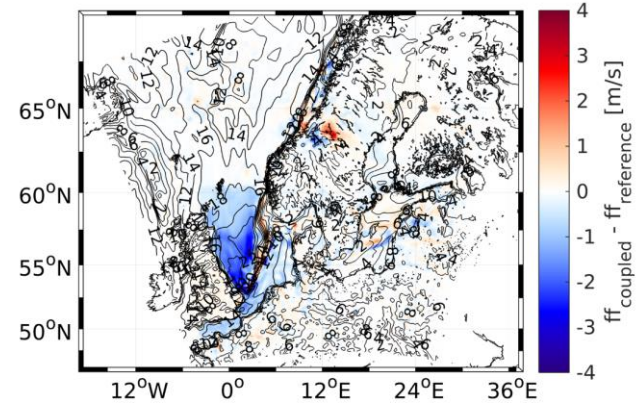

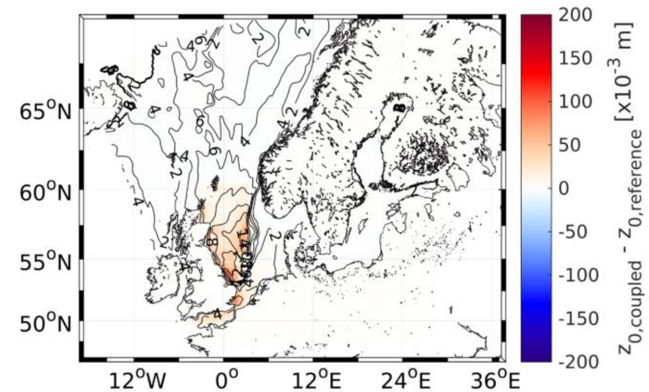

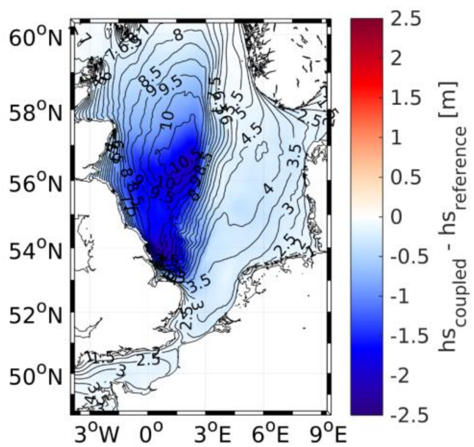

- Centre of low pressure system over North Sea
- Convergence Zone

INTRODUCTION

- Alternative calculation of exchange coefficients and wind input source function S_{in}
- Energy input from the wind to the waves determines the growth of waves due to wind
- Currently parameterised according to Janssen (1991)
- Some drawbacks:
  - No sheltering effect
  - Logarithmic wind profile
  - neither conserves momentum nor kinetic energy

→ To address these issues, the Wave Boundary Layer Model (WBLM, Du et al. (2017, 2019)) is implemented as a new wind input source function in WAM

INPUT SOURCE FUNCTION

Janssen (1991)

- $S_{in} = \beta_g N$
- $\beta_g = \frac{\rho_a}{\rho_w} C_\beta \, \omega \left(\frac{u_*}{c} max(cos(\theta - \phi), 0) \right)^2$
- $C_\beta = \frac{\beta_{max}}{\kappa^2} tanh(kh) \, \mu \, ln^4(\mu)$
- $\mu = \frac{g z_0}{c^2} tanh(kh) \, e^x$
- $x = \frac{\kappa}{\left(\frac{u_*}{c} + \alpha\right) cos(\theta - \phi)}$

WBLM (Du et al. 2017,2019)

- $S_{in} = \beta_g N$
- $\beta_g = \frac{\rho_a}{\rho_w} C_\beta \, \omega \left(\frac{u_*^l}{c} max(cos(\theta - \phi), 0) \right)^2$
- $C_\beta = \frac{\beta_{max}}{\kappa^2} \mu \, ln^4(\mu)$
- $\mu = \frac{g z}{c^2} tanh(kh) \, e^x$
- $x = \frac{\kappa}{\left(\frac{u_*^l}{c} + \alpha\right) cos(\theta - \phi)} - \frac{\kappa \, u(z)}{u_*^l}$

WAVE BOUNDARY LAYER MODEL

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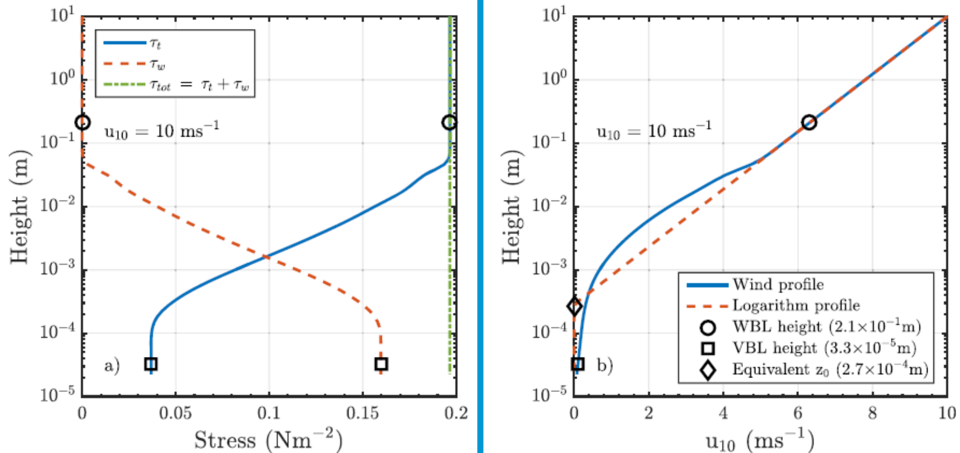


Du et al. (2017)

WBLM: $\tau = \tau_t + \tau_w = const$

$$u_*^l = \sqrt{\frac{\tau_t}{\rho_a}}$$

$$\tau_w = \rho_w \int \beta_g\, \omega^2\, N\, \frac{\vec{k}}{k}\, d\omega\, d\theta$$

JANSSEN: $\tau = u_*^2 = \left(\frac{\kappa\, u_{10}}{ln\left(\frac{z_{10}}{z_0}\right)}\right)^2$

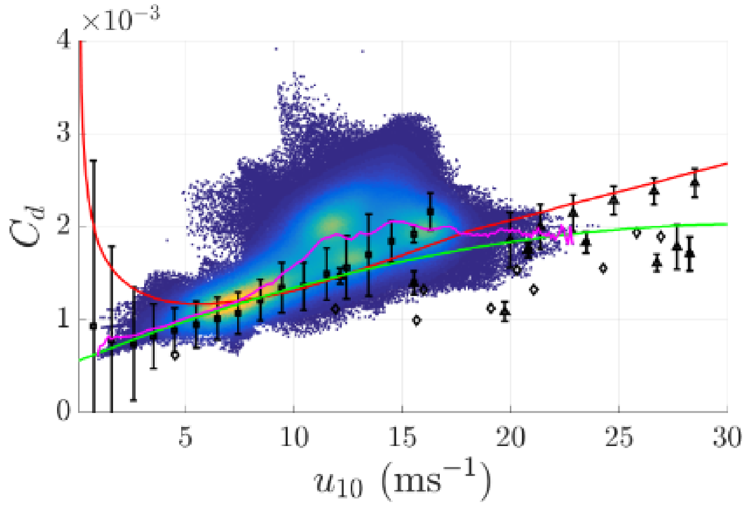
$$\tau_w = \frac{\rho_a}{\rho_w}\, g \int d\omega\, d\theta\, \beta_g\, N\, \vec{k}$$

WBLM: $\frac{du}{dz} = \left[\frac{\delta c}{z^2}\tau_w(z) + \frac{\rho_a}{\kappa z}\left|\frac{\tau_t(z)}{\rho_a}\right|^{\frac{3}{2}}\right] \times \frac{1}{\tau}$

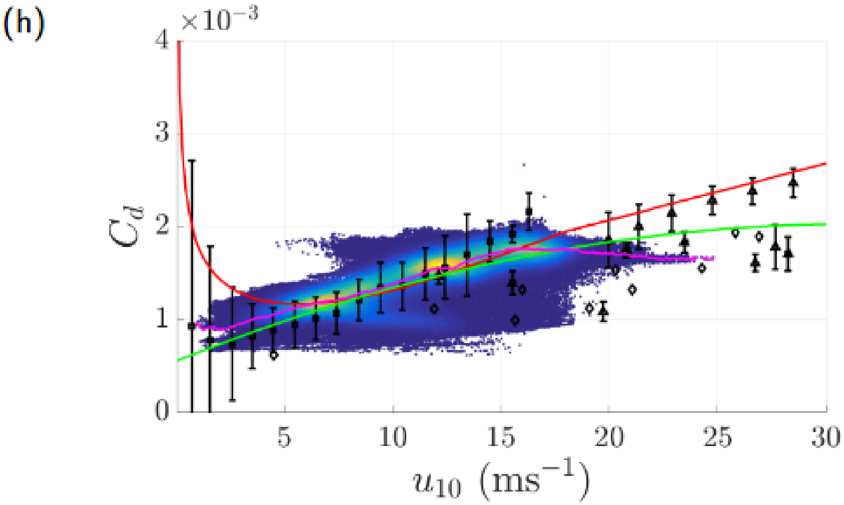
Log. Windprofile: $\frac{du}{dz} = \frac{u_*}{\kappa\, z}$

WAVE BOUNDARY LAYER MODEL

Janssen (1991)



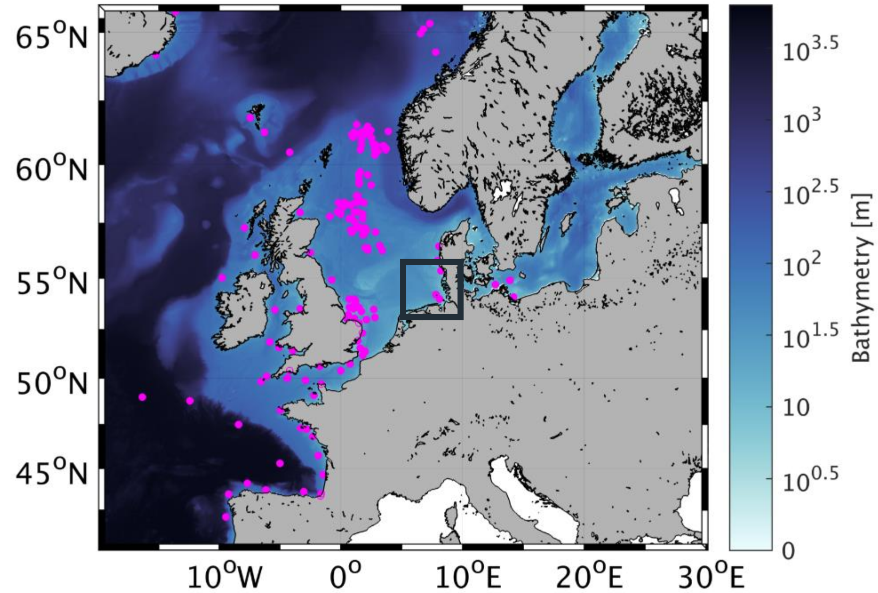
WBLM (Du et al. 2017,2019)



Du et al. (2017)

MODEL

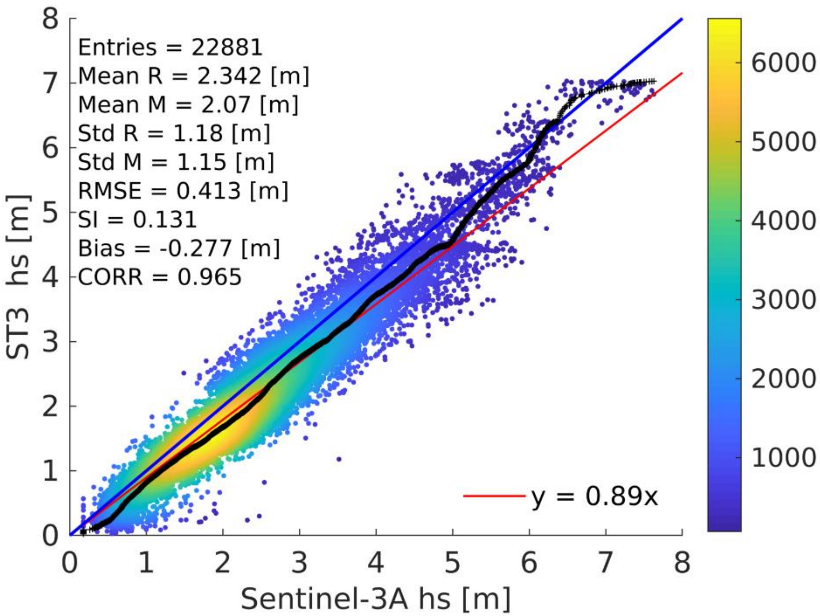
- Wind-wave model WAM v4.7
- Spectral model
- Includes: shallow water, depth refraction and wave breaking parameterizations
- Directional resolution:
  - Number of directions: 24
  - Number of frequencies: 30
- ERA5 wind forcing
- September 2017



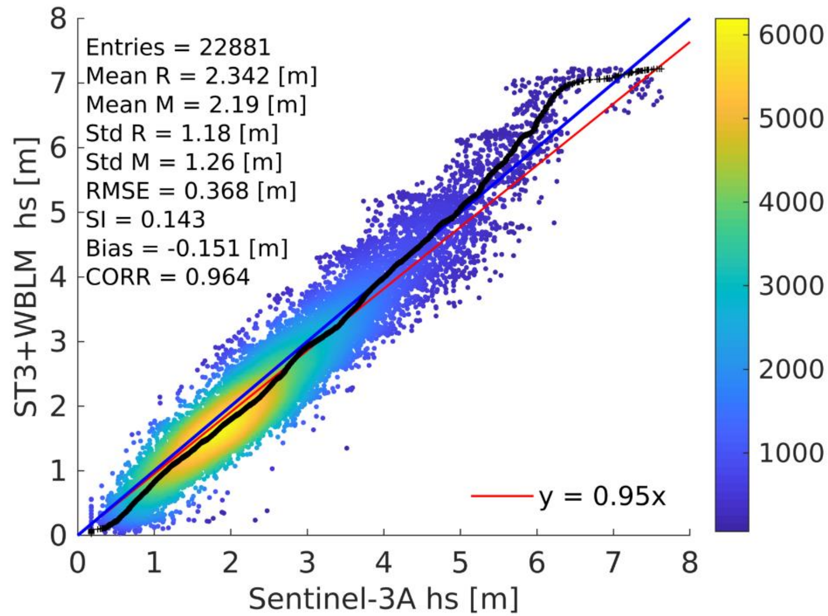
- Spatial resolution GCOAST:
  - dx: ~0.06°, dy: ~0.03°
- Spatial resolution GB:
  - dx: ~0.016°, dy: ~0.009°

GENERAL COMPARISON

Janssen (1991)



WBLM (Du et al. 2017,2019)



SIGNIFICANT WAVE HEIGHT DIFFERENCE

12.09.2017 05 UTC

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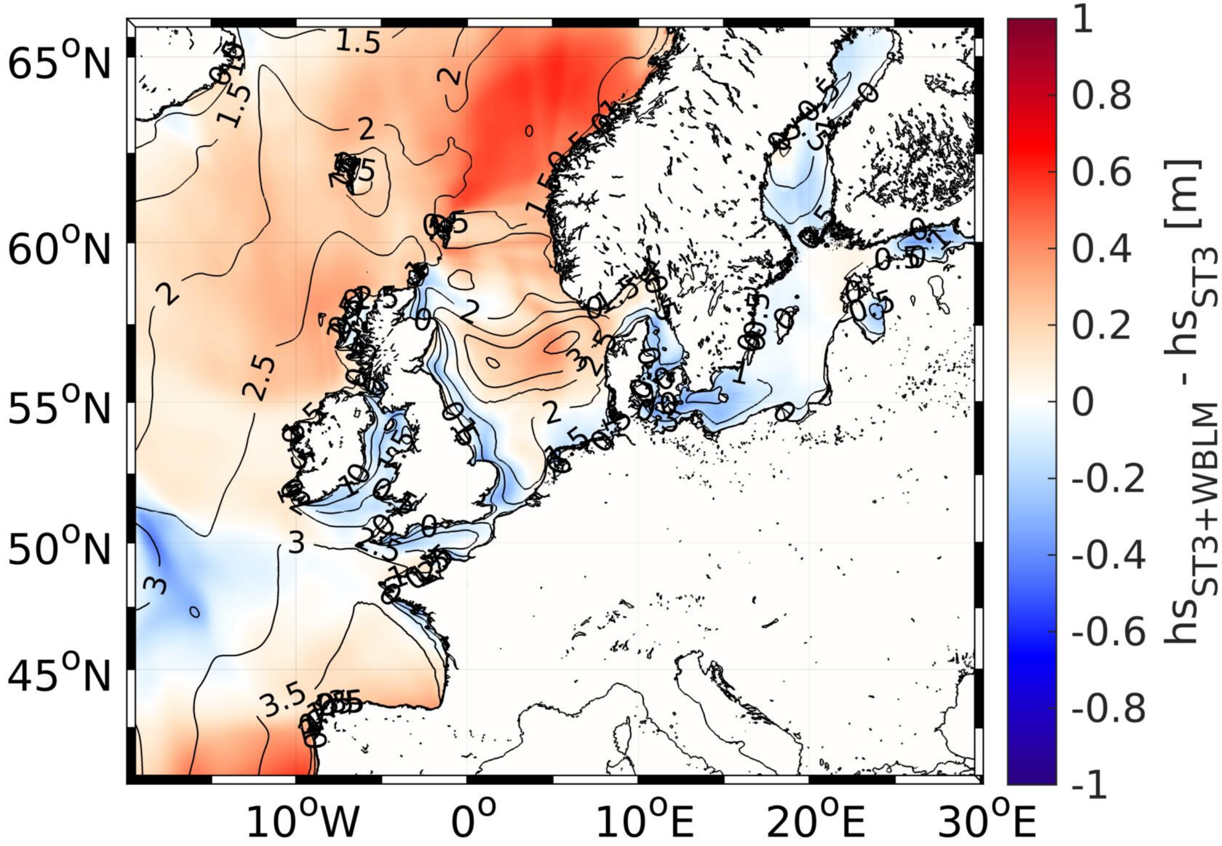
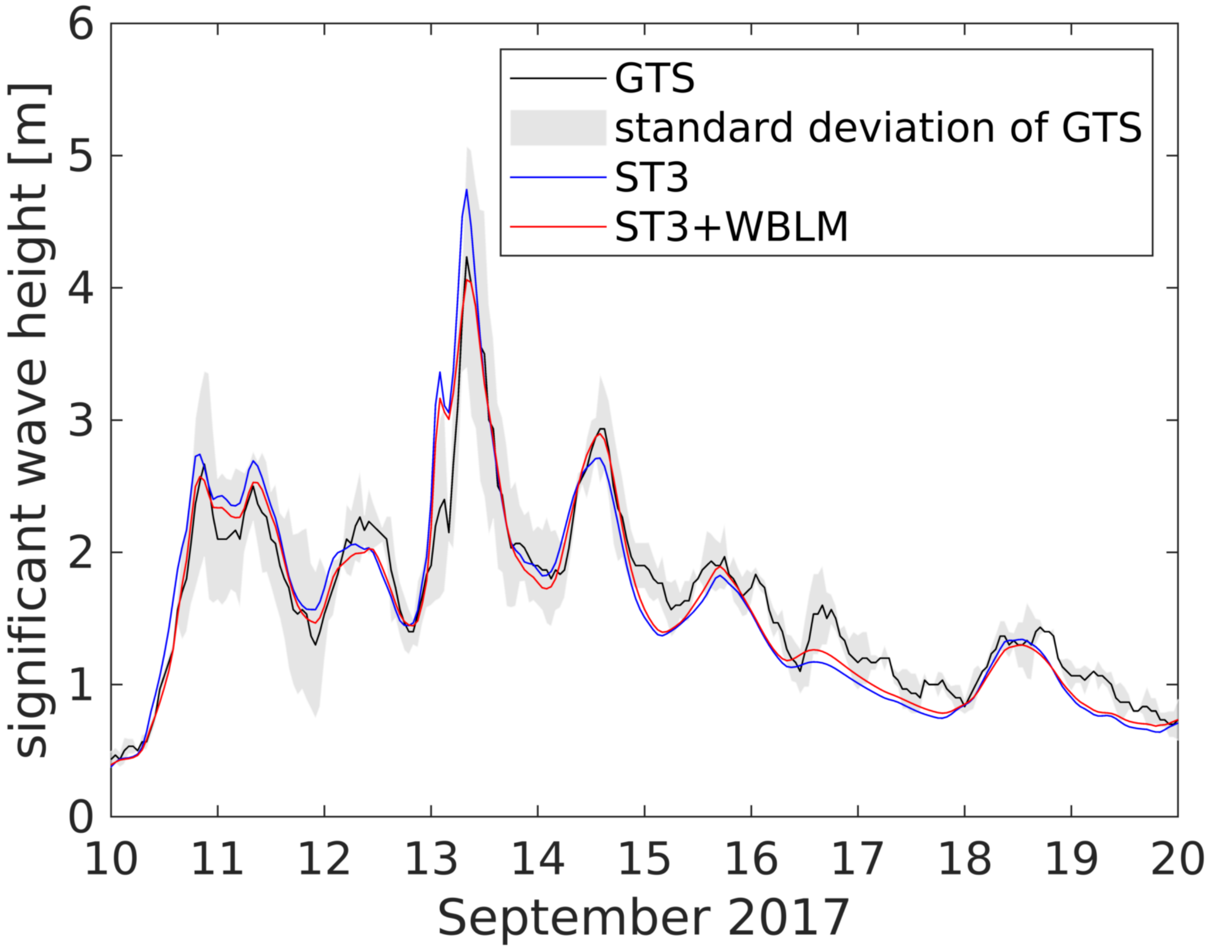
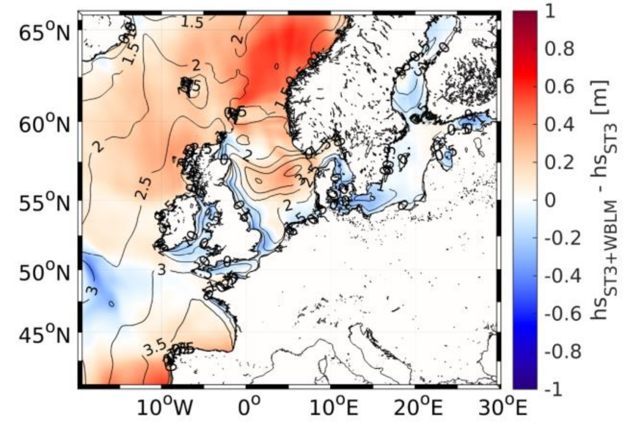


SIGNIFICANT WAVE HEIGHT BRITISH COAST





SIGNIFICANT WAVE HEIGHT GERMAN BIGHT

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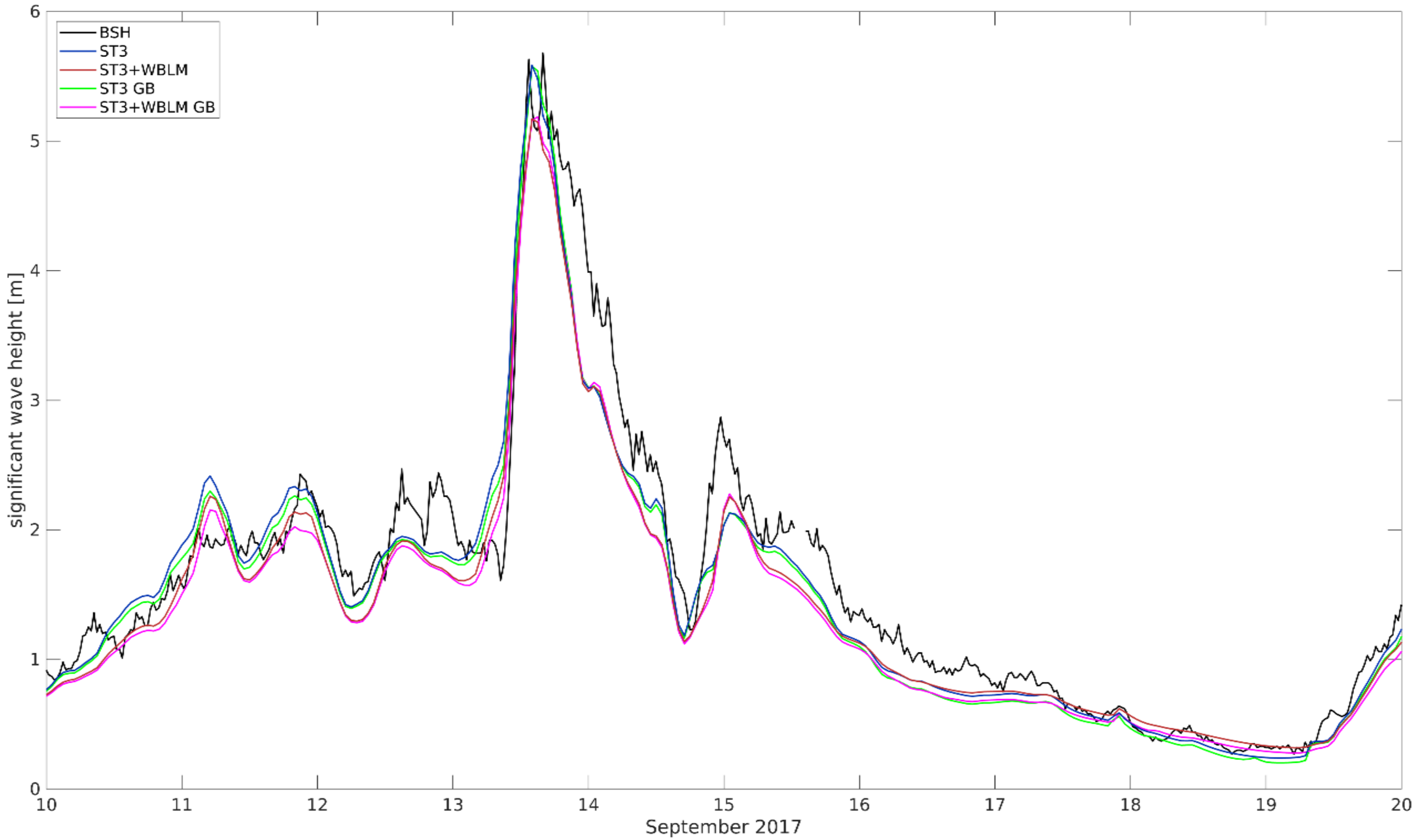
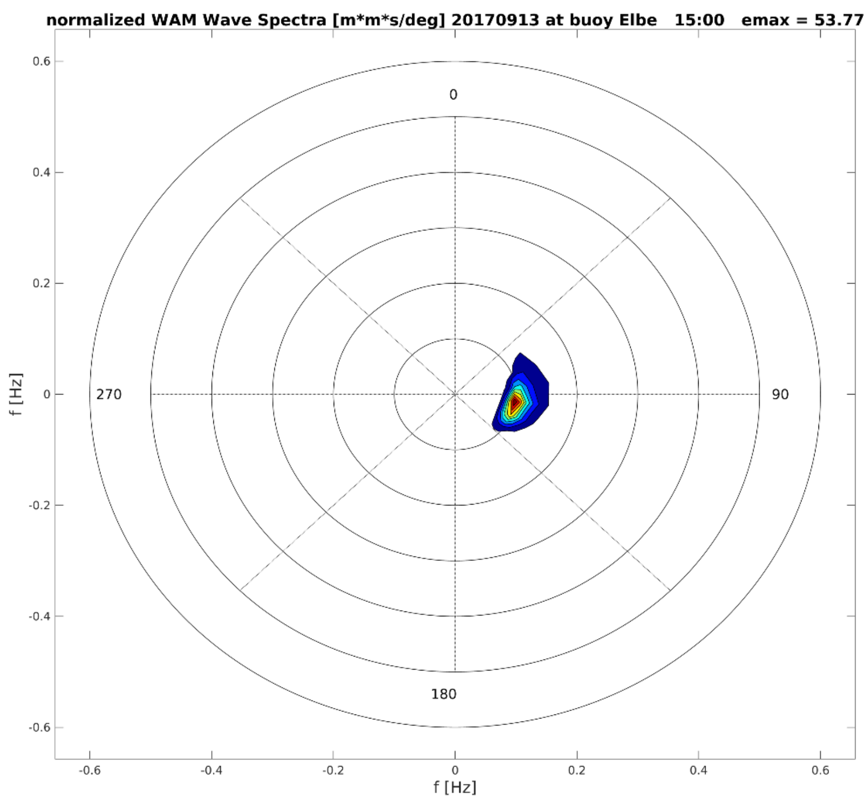


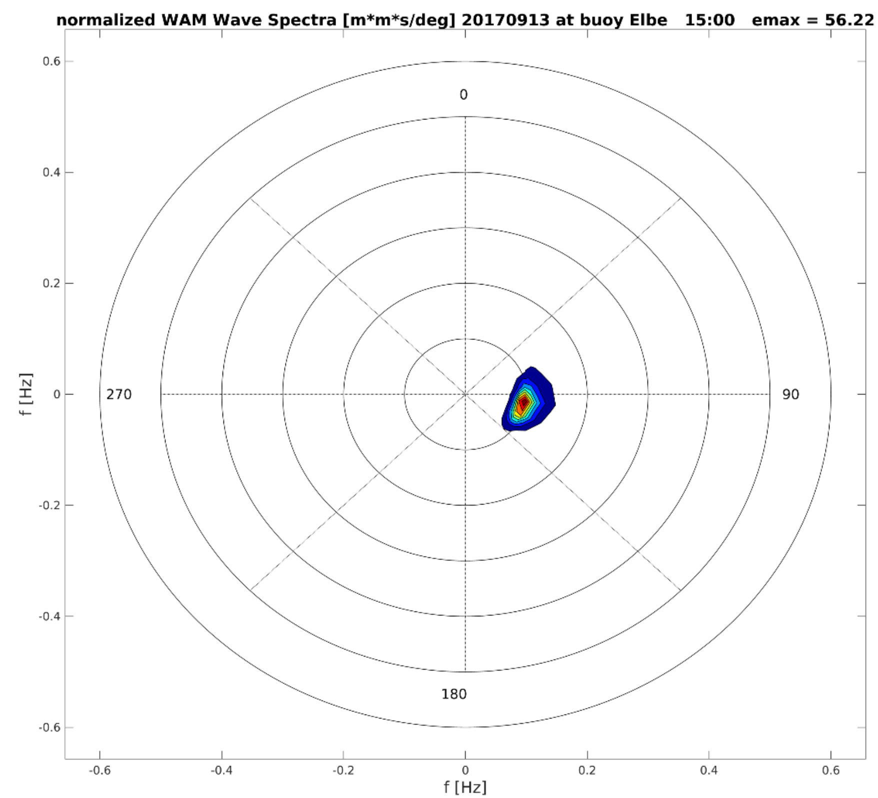
ENERGY SPECTRUM

Elbe buoy

Janssen (1991)

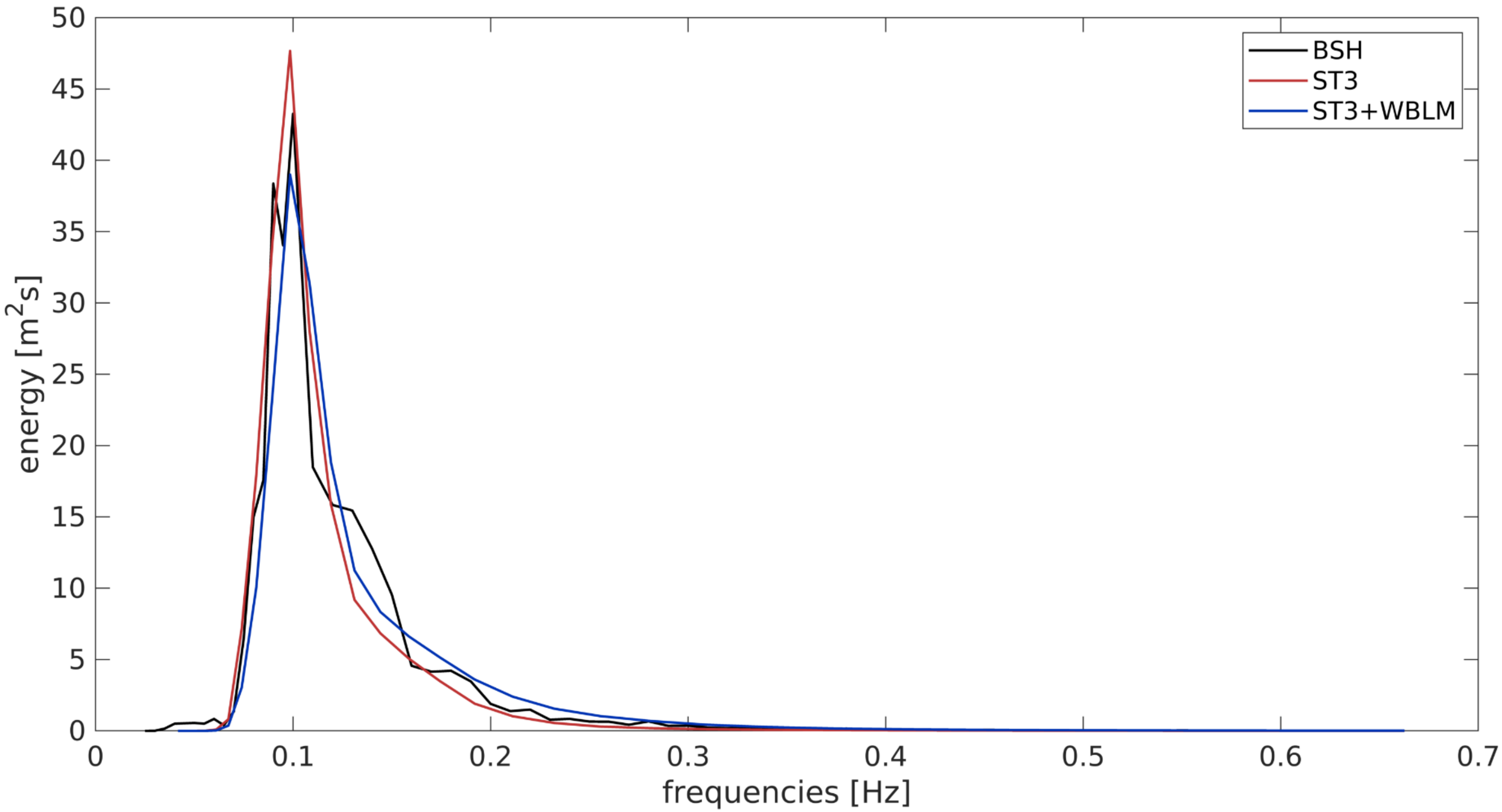


WBLM (Du et al. 2017,2019)



ENERGY SPECTRUM

Elbe buoy



ENERGY SPECTRUM

Bay of Biscay

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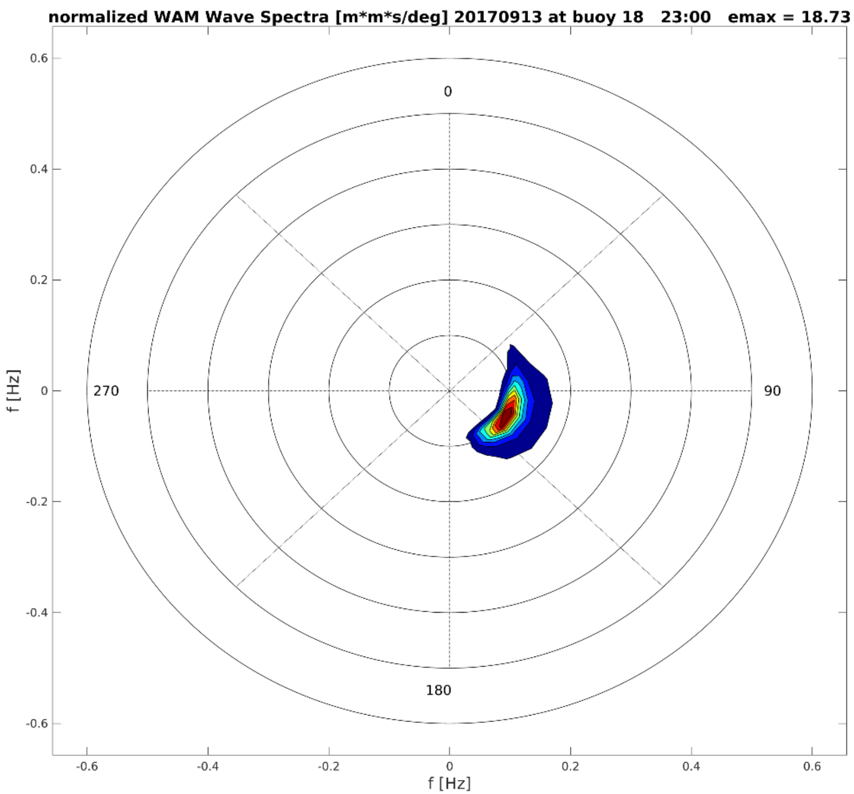
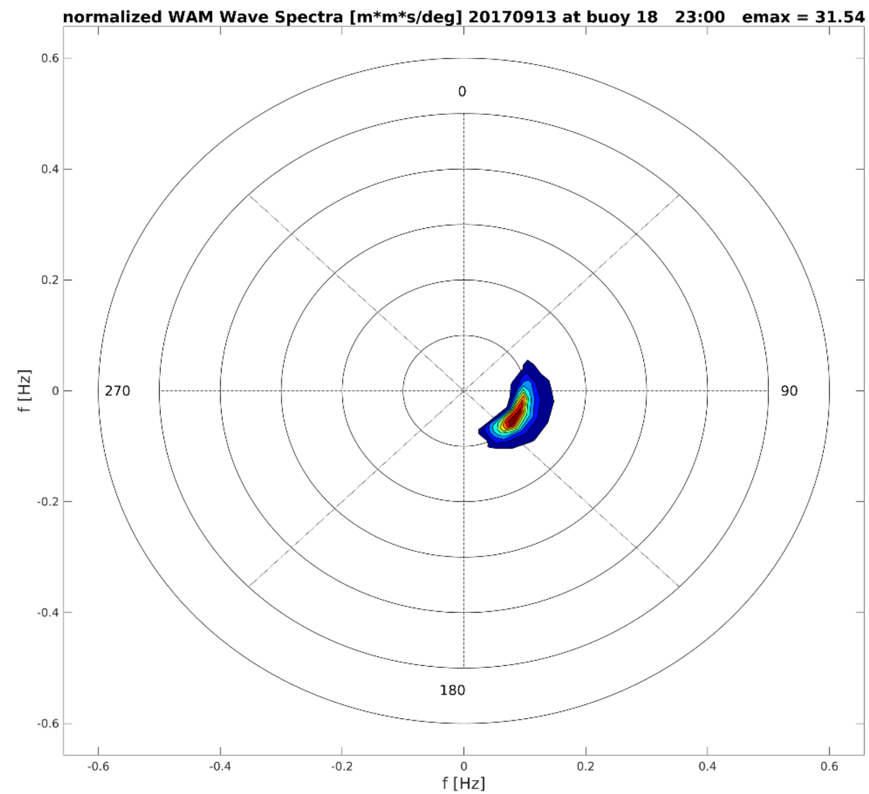
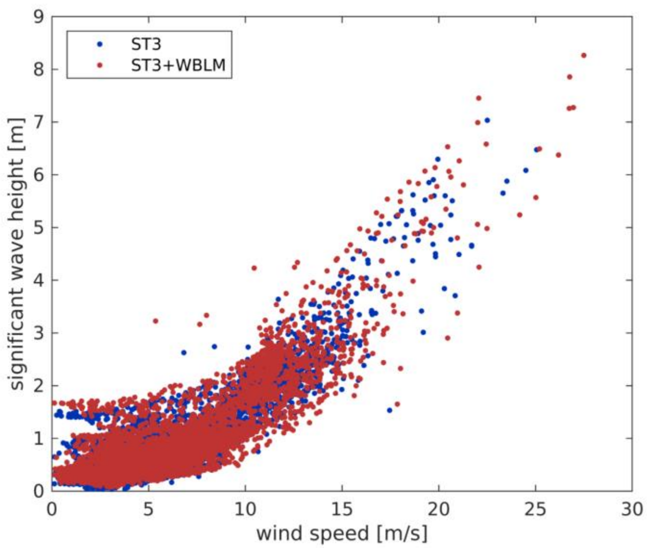
Janssen (1991)

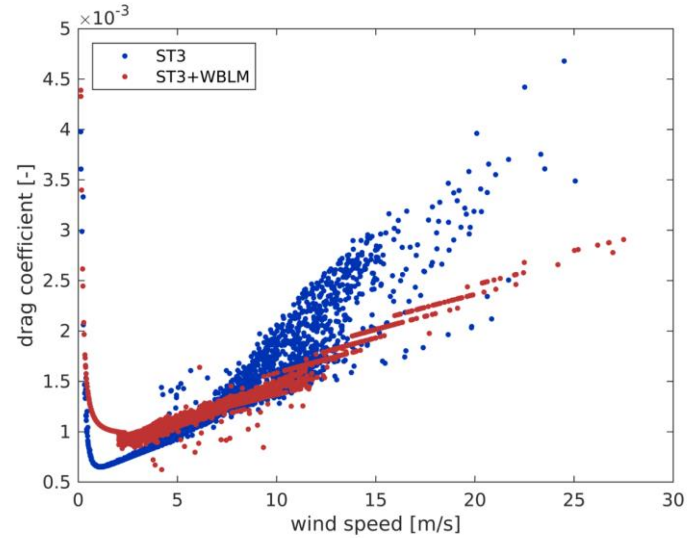


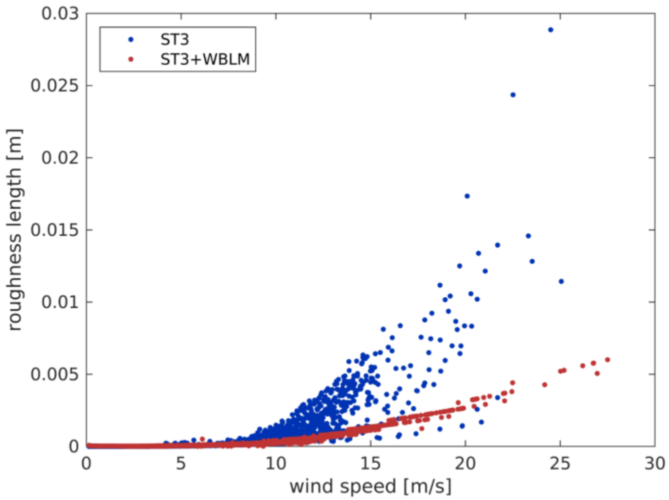
WBLM (Du et al. 2017,2019)

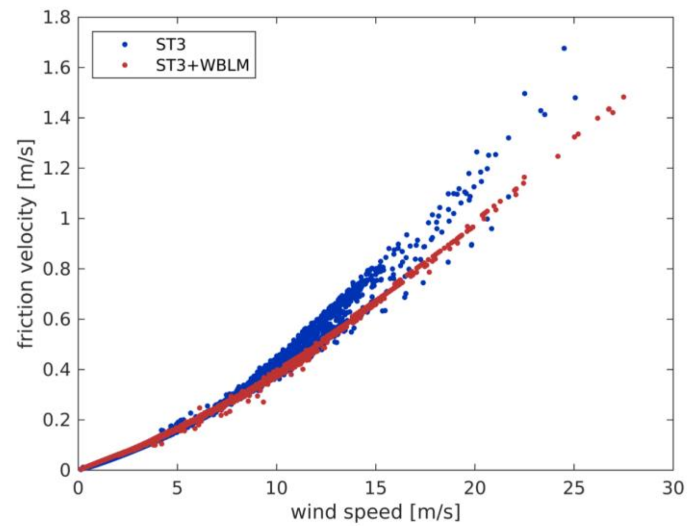


EXCHANGE PARAMETERS









SUMMARY

- WBLM implemented in WAM
- Shows similar results in significant wave height as Janssen
- Calculates wind profile within WBL more precisely
  - → More precise estimation of exchange coefficients between atmosphere-waves-ocean
  - → Relevant to offshore wind farms, atmosphere-ocean momentum and mass exchange (e.g CO_2 , transport of matter, pollutants, etc.)

OUTLOOK

- What are effects on coupling?
  - Where are the largest differences?
  - Determine differences for wind sea and swell
  - Spatial differences
  - Impact of grid resolution

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FOR PEOPLE AND THEIR FUTURE ENVIRONMENT

THANK YOU!

Anne Wiese

Institute for coastal research

anne.wise@hzg.de

Max-Planck-Straße 1

21502 Geesthacht

Helmholtz-Zentrum Geesthacht

Zentrum für Material- und Küstenforschung

GENERAL COMPARISON COUPLED MODEL

SIGNIFICANT WAVE HEIGHT

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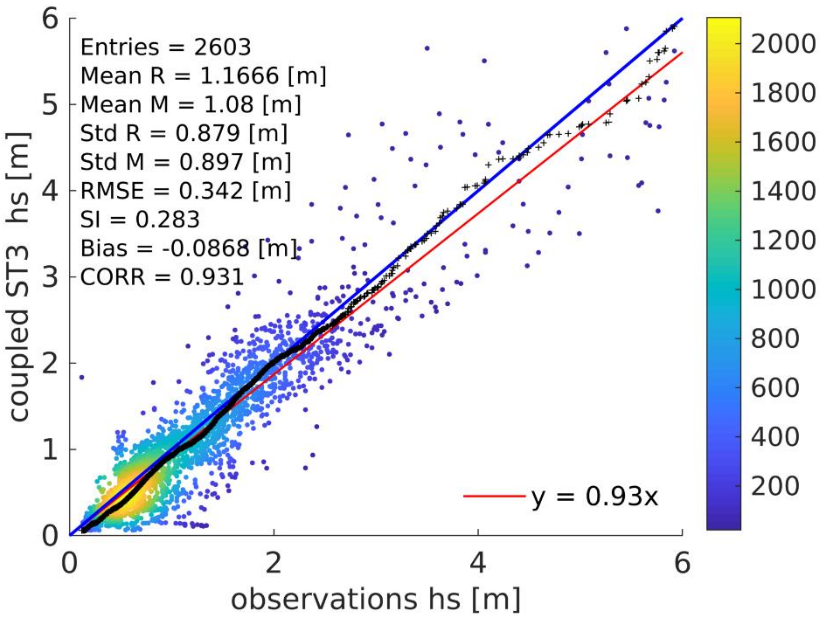
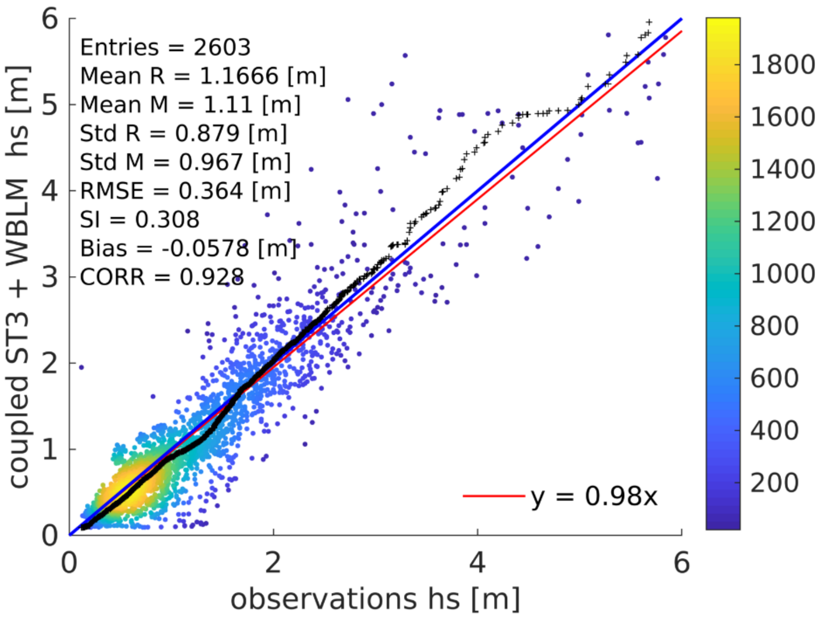
Janssen (1991)



WBLM (Du et al. 2017,2019)



GENERAL COMPARISON COUPLED MODEL

WIND SPEED

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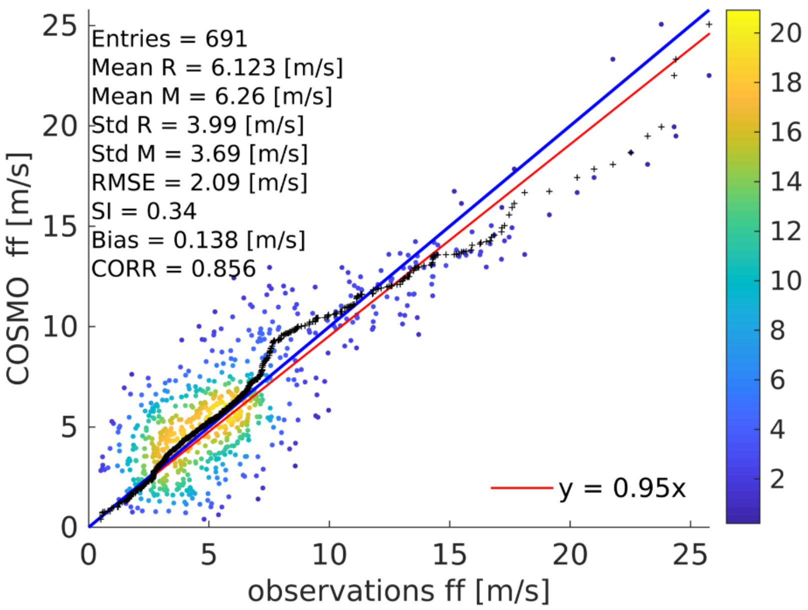
Janssen (1991)



WBLM (Du et al. 2017,2019)