Prediction of typhoon Waves with WBLM: Case of typhoon Lingling

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Background

- Exchanges of momentum and heat in the wave boundary layer (WBL) significantly impact on wind and waves.
- Hence, the parameterisation of the momentum fluxes (C_d, z_0) in the coupled atmosphere-wave models affects the predictions of ocean waves.
- ECMWF's coupled model OpenIFS v40r1 uses Janssen's (1991)[a] theoretical approach for calculating the momentum fluxes, based on the conservation of momentum in the Wave Boundary Layer (WBL).
- Janssen scheme has weaknesses; e.g., highly depends on the logarithmic profile, does not consider sheltering effects (for the version used) [1].
- Du et al. (2017, 2019)[b,c] used the WBLM in order calculate the input and dissipation sources functions.
- More importantly, typhoon predictions are still insufficient. Even though significant steps have been made towards better forecasts of wind and waves under typhoon conditions, improvements of the parameterisation of the momentum fluxes (drag coefficient C_d, roughness length z_0) are still needed.
- We present here progress on our work (https://doi.org/10.5194/egusphere-egu2020-3605) on the implementation of the Wave Boundary layer model (WBLM) in the coupled system of the OpenIFS, focusing on the typhoon Lingling.

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1. Note that OpenIFS v40r1 is not the operational cycle. Things like the sheltering mechanism have been corrected in the later versions of the model.

a. Janssen, P. A. E. M. (1991). Quasi-linear Theory of Wind-Wave Generation Applied to Wave Forecasting. *Journal of Physical Oceanography*, *21*(11), 1631–1642
b. Du, J., Bolaños, R., & Guo Larsén, X. (2017). The use of a wave boundary layer model in SWAN. Journal of Geophysical Research: Oceans, 122(1), 42–62
c. Du, J., Bolaños, R., Guo Larsén, X., & Kelly, M. (2019). Wave boundary layer model in SWAN revisited. Ocean Sci, 15, 361–377

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Methodology

Comparison of typhoon simulations with the default parameterization of S_{in} in OpenIFS (Janssen 1991) and the WBLM parameterisation based on Du et al. (2017, 2019).

$S_{in} = \beta_g N$	
Janssen (1991)	**Du et al. (2017, 2019)**
$\beta_g = \frac{\rho_\alpha}{\rho_w} C_\beta \omega \left(\frac{u_*}{c} \max(\cos(\theta - \varphi), 0)\right)^2$	$\beta_g = \frac{\rho_\alpha}{\rho_w} C_\beta \omega \left(\frac{u_*^l}{c} \max(\cos(\theta - \varphi), 0)\right)^2$
$\mu = \frac{g z_0}{c^2} \tanh(kh) e^x$ $x = \frac{\kappa}{\left(\frac{u_*}{c} + a\right) \cos(\theta - \varphi)}$	$\mu = \frac{g z}{c^2} \tanh(kh) e^x$ $x = \frac{\kappa}{\left(\frac{u_*^l}{c} + a\right) \cos(\theta - \varphi)} - \frac{\kappa u(z)}{u_*^l}$

Case Study – Typhoon Lingling

- Category: 4
- Highest winds: 140 mph
- Lowest pressure: 940 hPa
- Formed: August 31, 2019
- Extratropical: after 7 Sept 2019
- Dissipated: 8 Sept 2019

Model configuration

- Atmospheric model TL1279: 16km
- Wave model: ¼ degrees (~28km)
- Vertical layers: 91
- Directions: 36
- Frequencies: 36
- fmin/fmax: 0.035/1 Hz

In – situ data

Data is provided from the buoy observations supported by Yellow Sea Ocean/East China Sea Observation and Research Station of OMORN, are acknowledged.

Name	Lon (°E)	Lat (°N)	Height (m)
S6	123.135	30.715	10

Department of Engineering
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Results

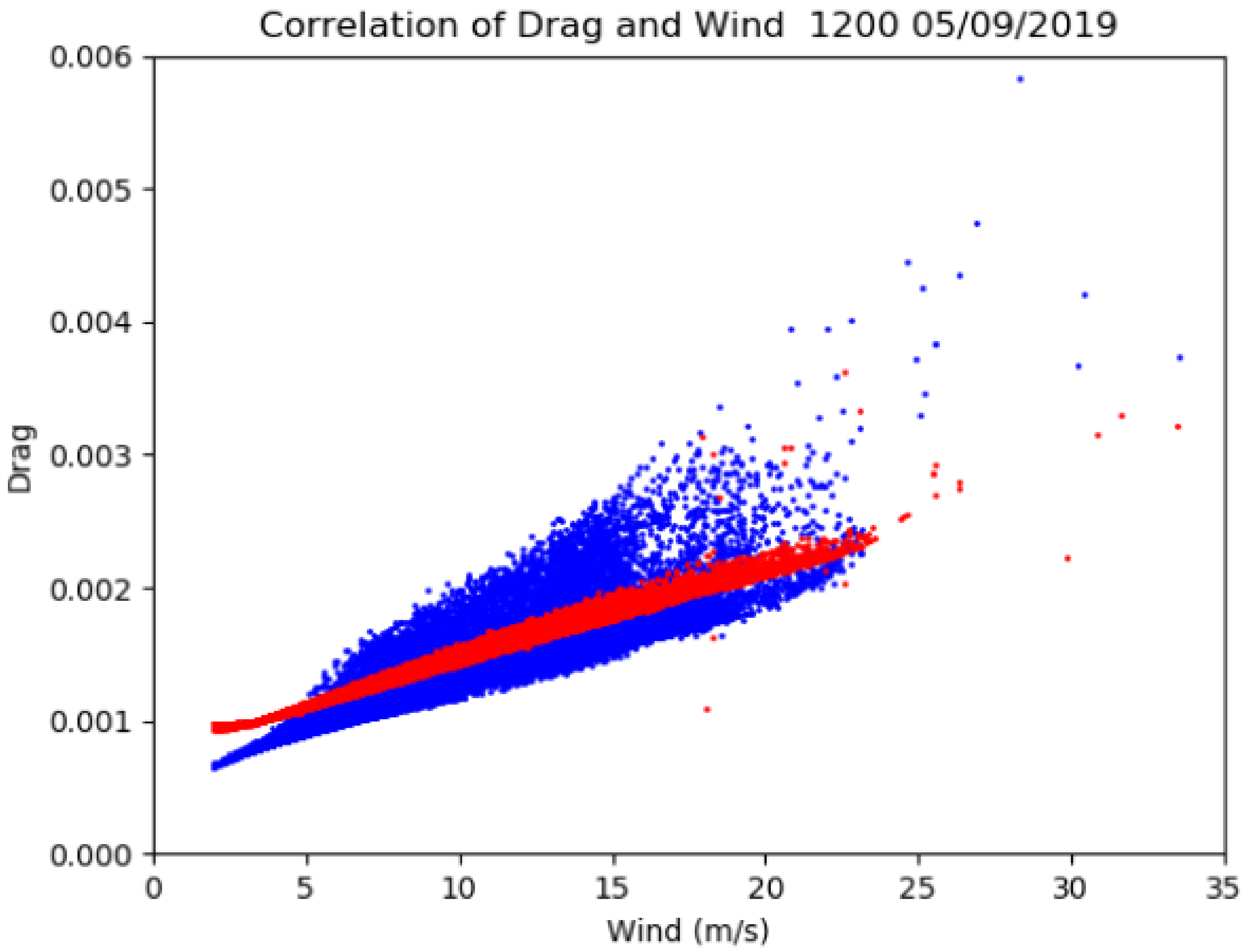

Figure 1. Comparison of drag coefficients from the Janssen (1991) model (blue) and WBLM (red).

The drag coefficient given from the WBLM is closer to the best fit, while Janssen's scheme gives bigger scatter. WBLM it also gives slightly higher mean Cd from Janssen.

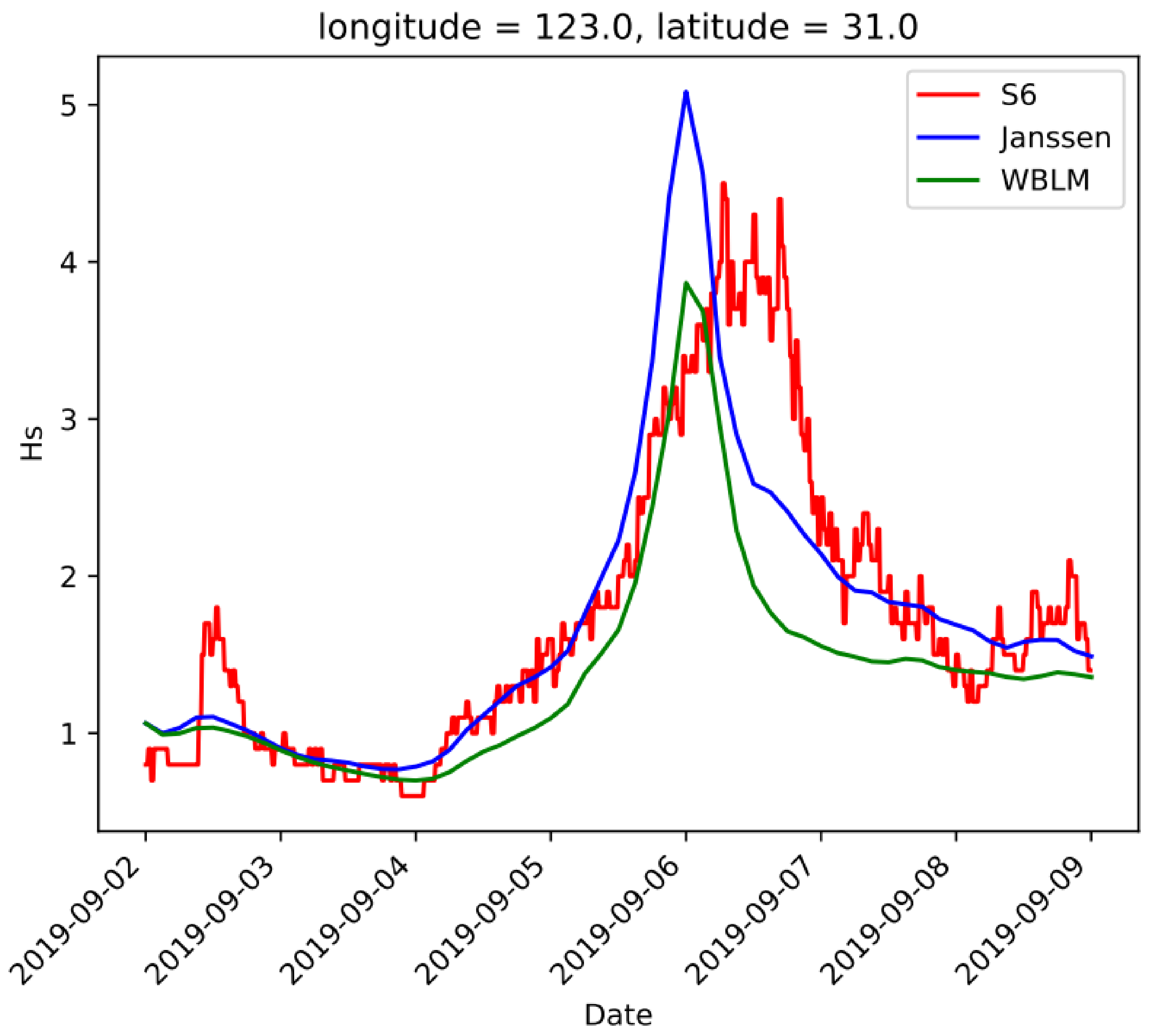

Figure 2. Comparison of predicted significant wave height from Janssen model (blue) and WBLM (green), with the in-situ observations (red) at the Yellow Sea/East China Sea

Janssen model overestimates the peak wave height, while WBLM shows a slight underestimation

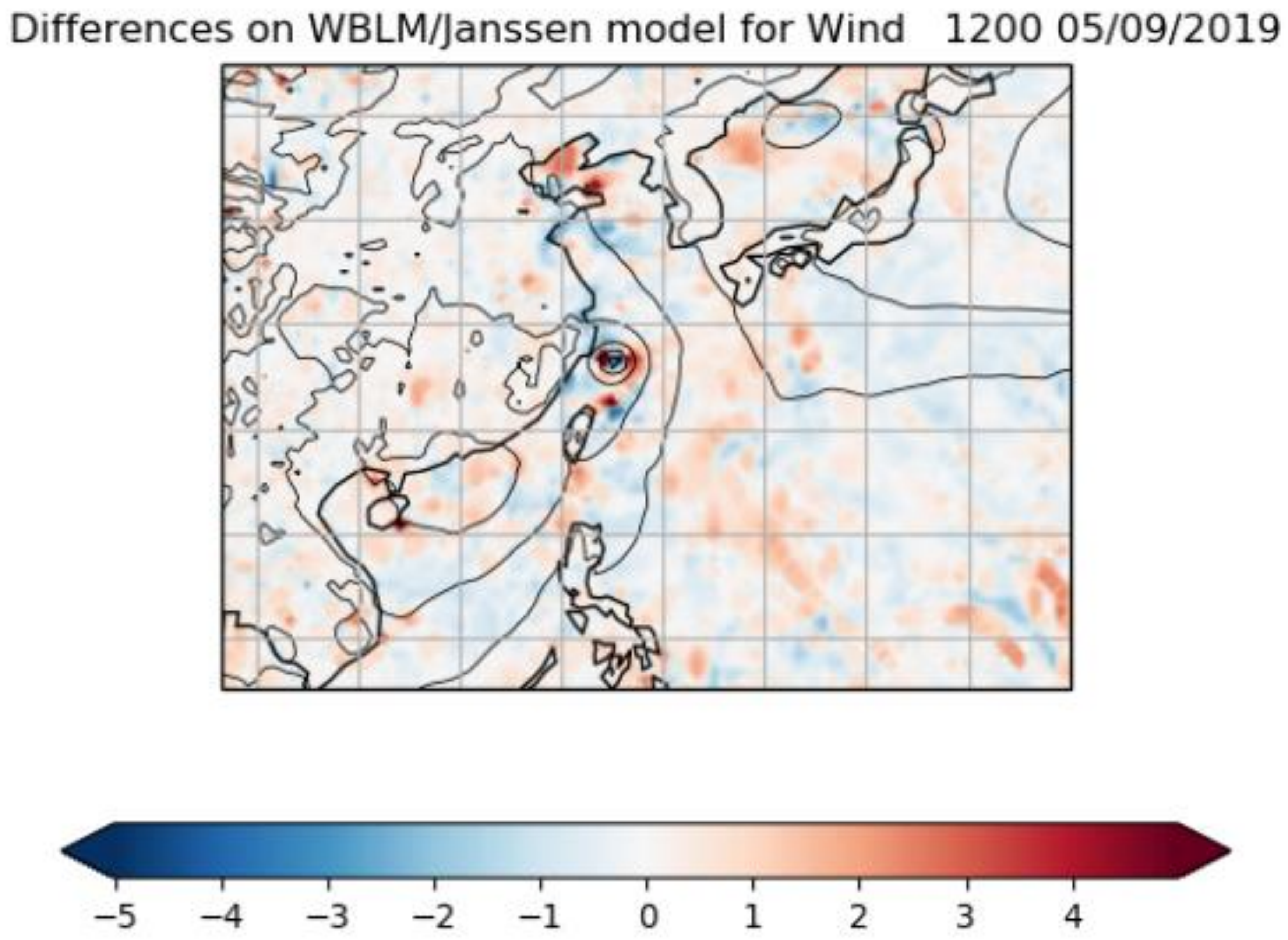

Figure 3 A snapshot of the wind differences between the two schemes, with the mean sea level pressure computed by the WBLM.

There are generally higher winds from the WBLM scheme than from Janssen. This can be seen be stronger the N/NE part of the cyclone.