White cap measurements and parameterizations based on the dissipation source term

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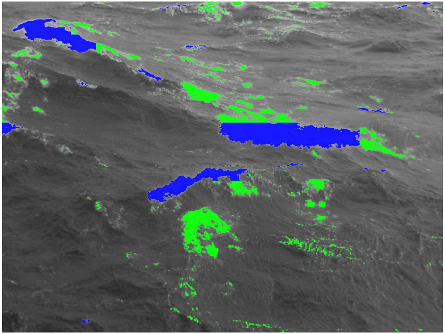

Outline of presentation

- Whitecaps and their relation to the dissipation of ocean waves
- Parameterizing wave breaking with a spectral wave model
- Measuring whitecaps
- Parameterizing whitecap coverage
- Conclusions and further work

Motivation

Estimates of the energy dissipated from the oceanic wave field due to wave breaking is needed for among other things

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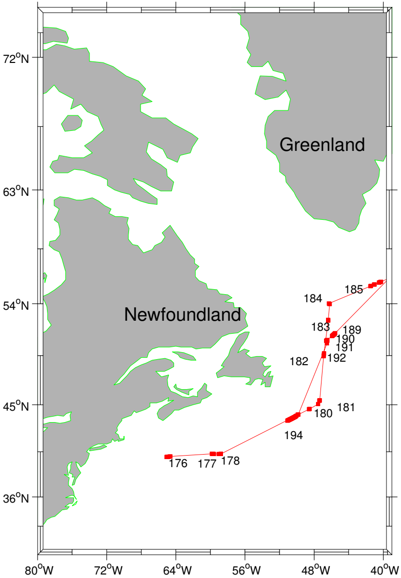
- calibrating remotely sensed estimates of sea surface temperature

- Parameterizing white cap coverage and comparing it to observations is an indirect estimate of our ability to model the dissipation from breaking waves

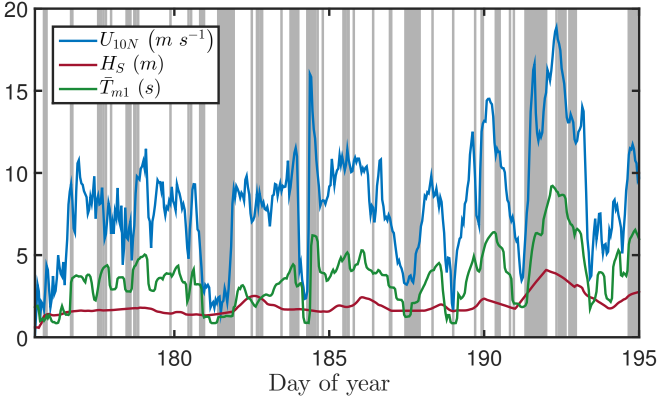
Observing whitecaps

Cruise track R/V Knorr June-July 2011. Day-of-year is marked along the cruise track and stations are marked as red squares.

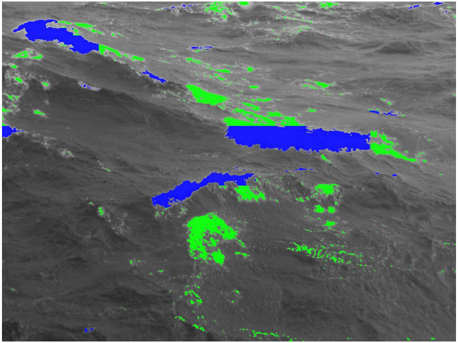


Observing whitecaps

Time series of neutral wind speed (U_{10N}), modeled significant wave height (H_s), mean period of the modeled wind-wave spectra ($\bar{T}$) during the North Atlantic campaign of 2011. The grey columns mark the periods during which whitecap coverage fraction was measured.



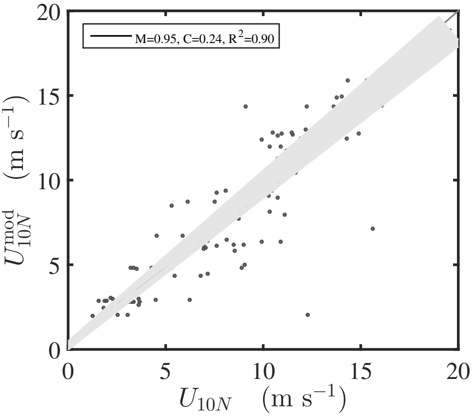
Observing whitecaps



- Whitecaps observed with 5 mega pixel 16 mm camera mounted on R/V Knorr.
- $>$ 114,000 images were processed first with Automated Whitecap Extraction (AWE) algorithm (Callaghan *et al*, 2009)
- Secondly, manual inspection using the Spatial Separation of Whitecap Pixels (SSWP) method (Scanlon and Ward, 2013) distinguishes active breaking (stage A, blue) from decaying (stage B, green)

Wave model integration

- The ECWAM wave model was rerun for the cruise period with 11-km spatial resolution. Wave fields are output with 1-hourly temporal resolution.
- The wind was taken from operational analyses which compare well with the observed wind speed



Parameterizing whitecaps from a spectral wave model

Craig and Banner (1994) assumed that the energy flux from breaking waves

$$\Phi_{\mathrm{oc}} = \rho_{\mathrm{w}} g \int_0^{2\pi} \int_0^{\infty} S_{\mathrm{ds}} \, \mathrm{d}\omega \mathrm{d}\theta \; [\mathrm{W\,m^{-2}}] \tag{1}$$

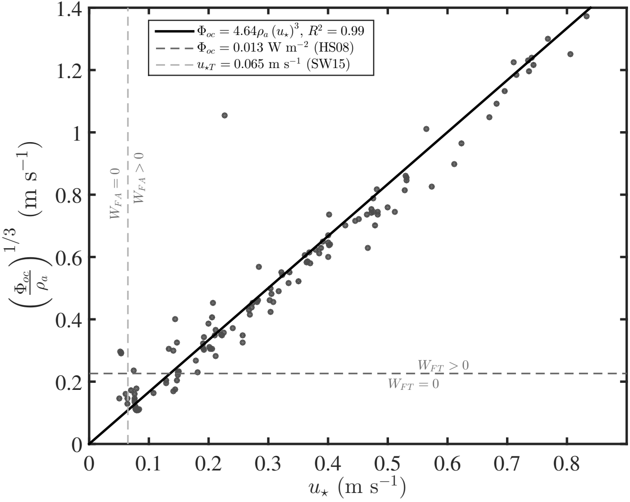
is proportional to the cube of the friction velocity, ie,

$$\Phi_{\mathrm{oc}} \approx \rho_{\mathrm{w}} \alpha_{\mathrm{CB}} w_*^3 = \rho_{\mathrm{a}} m u_*^3, \tag{2}$$

where w_* is the water friction velocity and typically $50 < \alpha_{\mathrm{CB}} < 150$. Craig and Banner (1994) assumed $\alpha_{\mathrm{CB}} = 100$ (or, equivalently, an air-side coefficient $m \approx 3.5$)

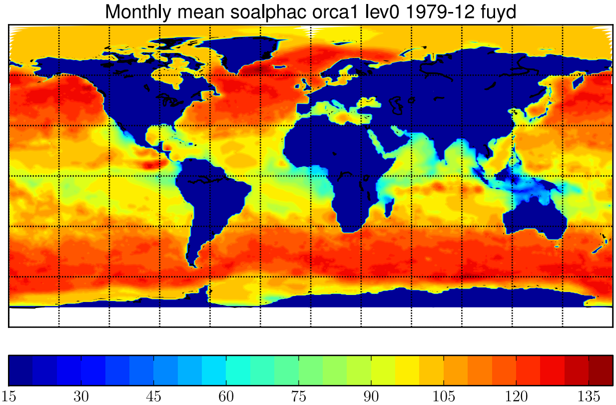
Parameterizing whitecaps from a spectral wave model

The ECWAM model integration for the cruise period shows that this proportionality is a good first order approximation



Parameterizing whitecaps from a spectral wave model

But the proportionality factor α_{CB} is not constant, neither geographically nor in time as it depends on the maturity of the sea state. A one-month average shows that there are large geographical differences



Parameterizing whitecaps from a spectral wave model

Kraan *et al* (1996) parameterized the whitecap fraction (area covered by whitecaps) from the flux Φ_{oc} as

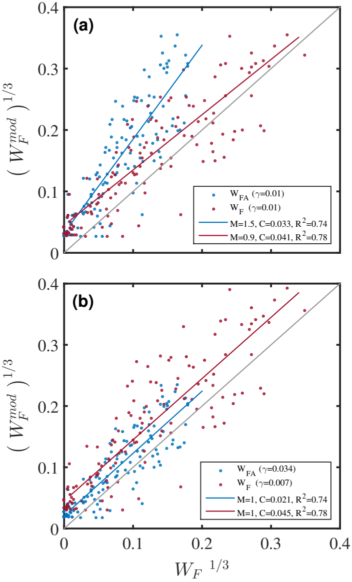
$$W_F^{\mathrm{mod}} = \frac{\Phi_{oc}}{\gamma \rho_{\mathrm{w}} g \bar{\omega} E}, \tag{3}$$

where $\bar{\omega} = 2\pi/\bar{T}$ is the circular mean frequency, γ a tuning factor and $E = (H_{\mathrm{s}}/4)^2$.

Parameterizing whitecaps from a spectral wave model

The relationship between observed and modelled whitecap coverage is quite impressive, but there is still some room for tuning. The factor γ is here used to separately tune W_{FA} and W_{F}.

- A: $\gamma = 0.01$ for both active and total whitecap coverage
- B: γ set separately for the active and the total whitecap coverage improves the fit somewhat. The correlation remains unchanged at $R = 0.88$ for the total whitecap.

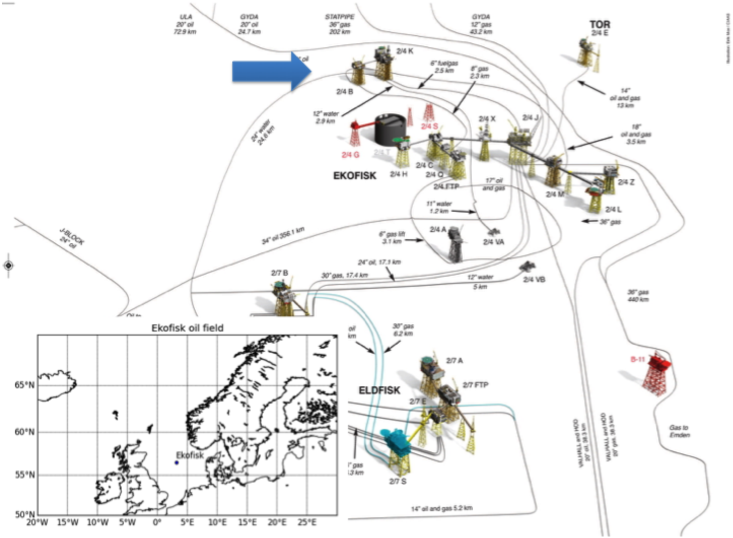


Conclusions

1. The manual Spatial Separation of Whitecap Pixels (SSWP) method is found to accurately distinguish between stage A and stage B whitecaps
2. The Kraan *et al* (1996) parameterization is found to yield a good parameterization of the total whitecap coverage
3. Rerunning the wave model improved the results compared with using ERA-Interim estimates with six-hourly resolution
4. The parameterization is straightforward to implement as it relies on integrated parameters only

Further work

Measuring wave breaking continuously from a fixed platform in the Central North Sea is planned (Norwegian WAVEMIX proposal)



Further work

The footbridge is located 22 m above still water level, facing N-NW, with a laser array already in place and a WaveRider buoy nearby.

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20 years is a long time

Kraan *et al* (1996)

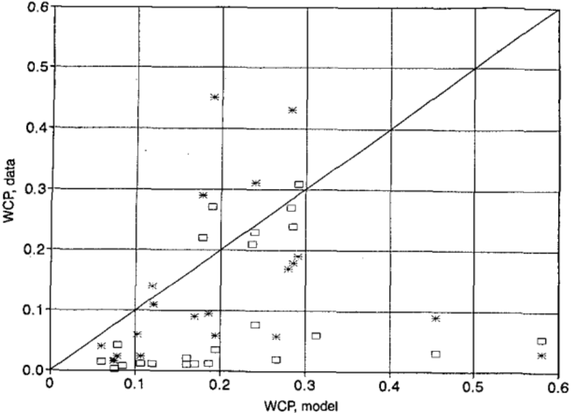

FIG. 3. Direct comparison between the modeled and measured whitecap percentages (WCPs). Asterisks—WC camera; squares—BR camera.