White cap measurements and parameterizations based on the dissipation source term

Ø Breivik, B Scanlon, J-R Bidlot, P A E M Janssen, AH Callaghan and B Ward
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
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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)
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.
Craig and Banner (1994) assumed that the energy flux from breaking waves

$$\Phi_{oc} = \rho_w g \int_0^{2\pi} \int_0^{\infty} S_{ds} d\omega d\theta \ [W \ m^{-2}]$$

(1)

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

$$\Phi_{oc} \approx \rho_w \alpha_{CB} w_*^3 = \rho_a m u_*^3,$$

(2)

where $w_*$ is the water friction velocity and typically $50 < \alpha_{CB} < 150$. Craig and Banner (1994) assumed $\alpha_{CB} = 100$ (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.

\[
\Phi_{oc} = 4.64 \rho_a (u_*)^3, \quad R^2 = 0.99
\]

\[
\Phi_{oc} = 0.013 \text{ W m}^{-2} \text{ (HS08)}
\]

\[
u_* T = 0.065 \text{ m s}^{-1} \text{ (SW15)}
\]
Parameterizing whitecaps from a spectral wave model

But the proportionality factor $\alpha_{CB}$ 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.
Kraan et al (1996) parameterized the whitecap fraction (area covered by whitecaps) from the flux $\Phi_{oc}$ as

$$W_F^{\text{mod}} = \frac{\Phi_{oc}}{\gamma \rho_w g \bar{\omega} E},$$

(3)

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

Parameterizing whitecaps from a spectral wave model
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 $\gamma$ is here used to separately tune $W_{FA}$ and $W_F$.

- A: $\gamma = 0.01$ for both active and total whitecap coverage
- B: $\gamma$ 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.

References:

20 years is a long time

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