Modeling whitecaps on global scale

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AI41A: Fluxes and Physical Processes Near the Air-Sea Interface: Observations and Modeling

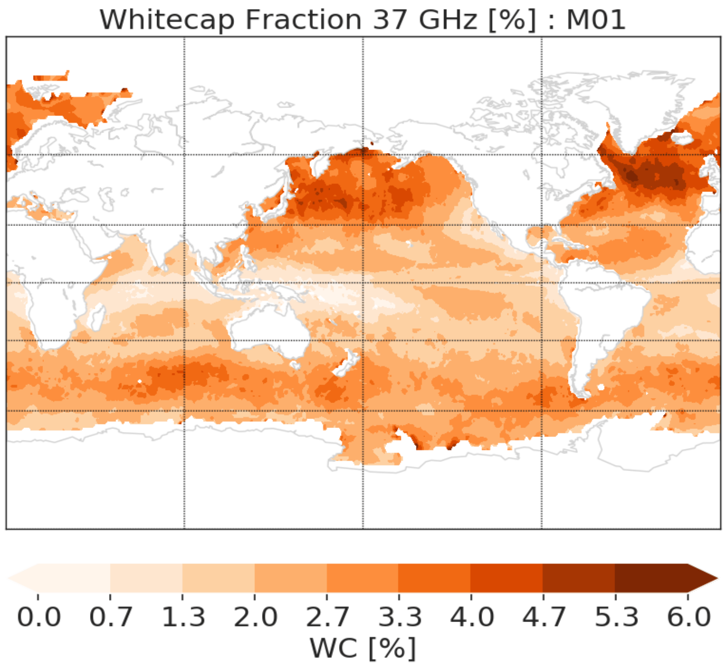
Abstract # : AI41A-05

AGU100 ADVANCING EARTH AND SPACE SCIENCE

Air sea processes and whitecaps (W)

- Air-sea exchange
  - Heat, momentum, aerosols and gases
- Sea surface albedo
- Atmospheric correction of ocean color sensors
- Model predictions of ocean surface layer processes

Global observations of W from satellite at multiple frequencies can help quantify the W variability



Global whitecap retrievals (M. D. Anguelova, NRL)

Whitecap models : Wind dependence

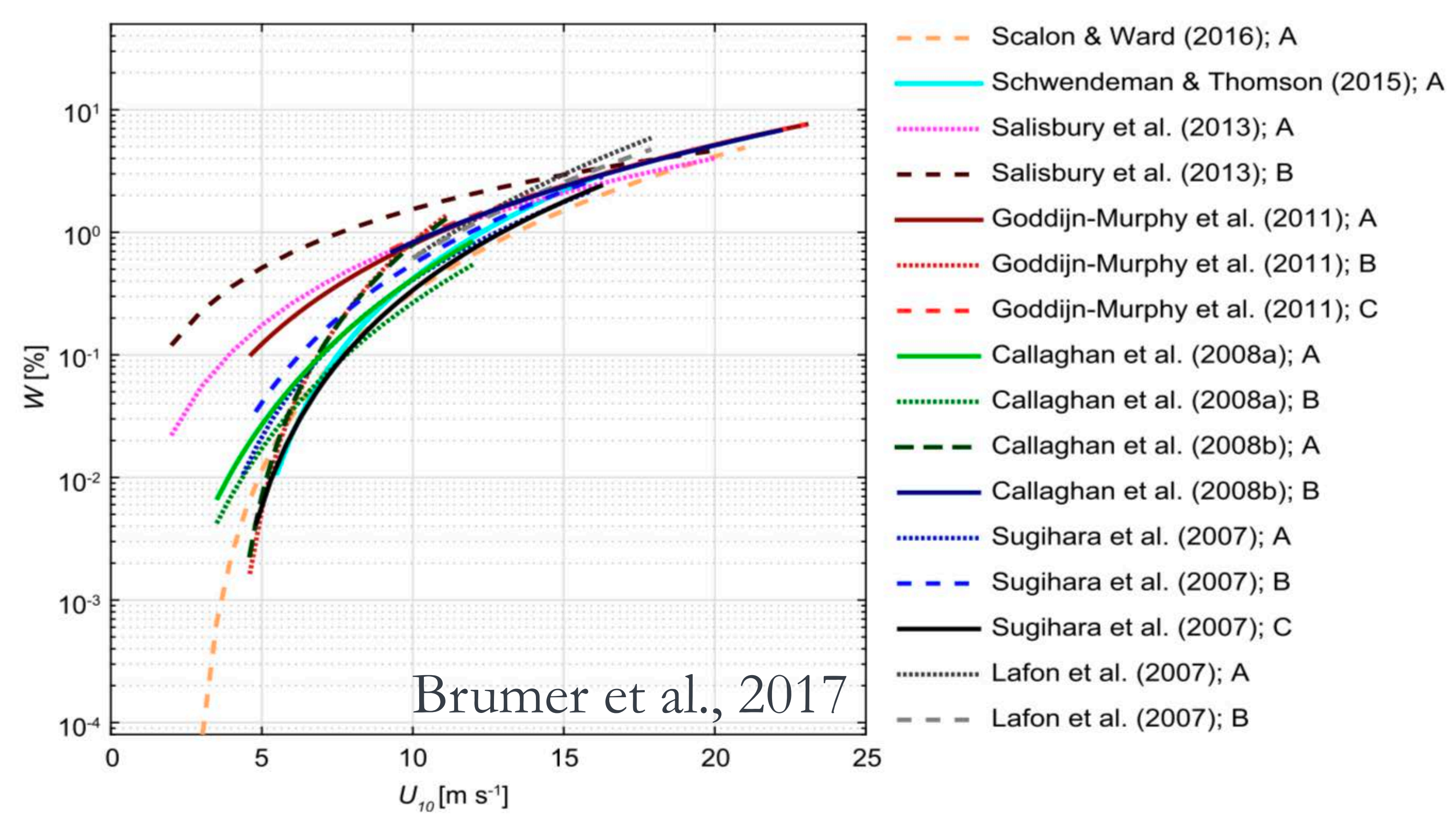
At a given wind speed, W variability is ~1-2 orders of magnitude

$$W = aU_{10}^{n}$$
(e.g. Monahan, 1971)

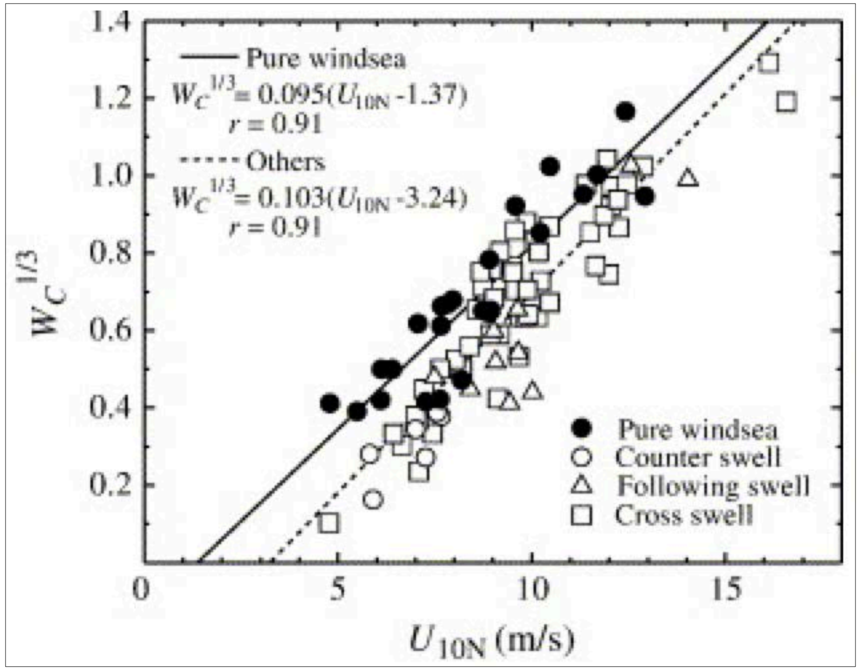
$$W = au_{*}^{n}$$
(e.g. Wu, 1988)

$$W = a(U_{10} - b)^{n}$$
(Goddijn-Murphy et al. (2011))

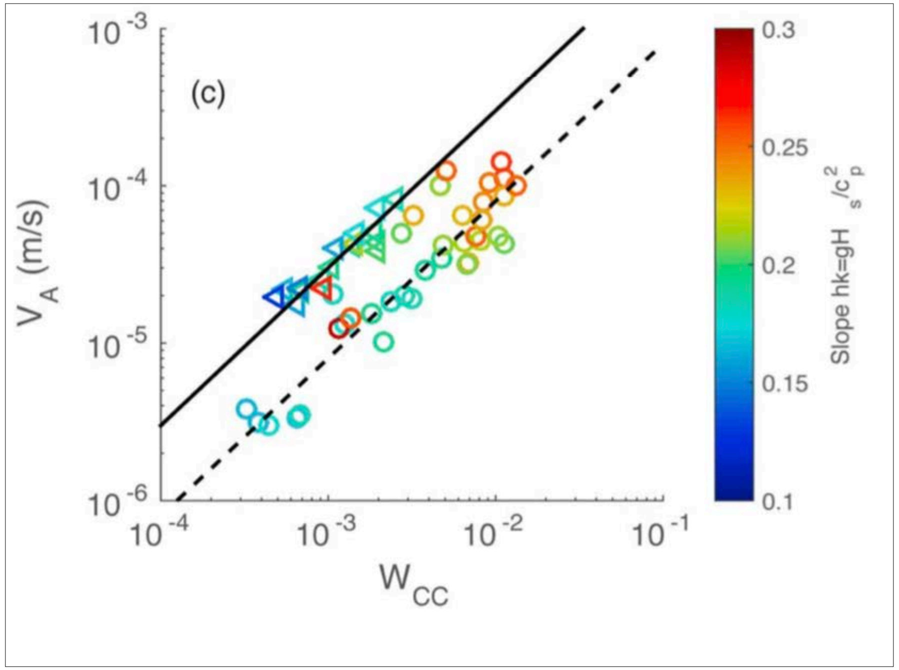
$$W = f\ (Wind\ history)$$
(e.g. Callaghan et al., 2008)



Variation of W with sea state



Sugihara et al. 2007



Deike et al. 2017

Wave based W

$$W = aRe_b^n$$

(e.g. Toba and Koga , 1986)

$$W = a\left(\frac{c_p}{u_*}\right)^n$$

(e.g. Scanlon and Ward (2016)

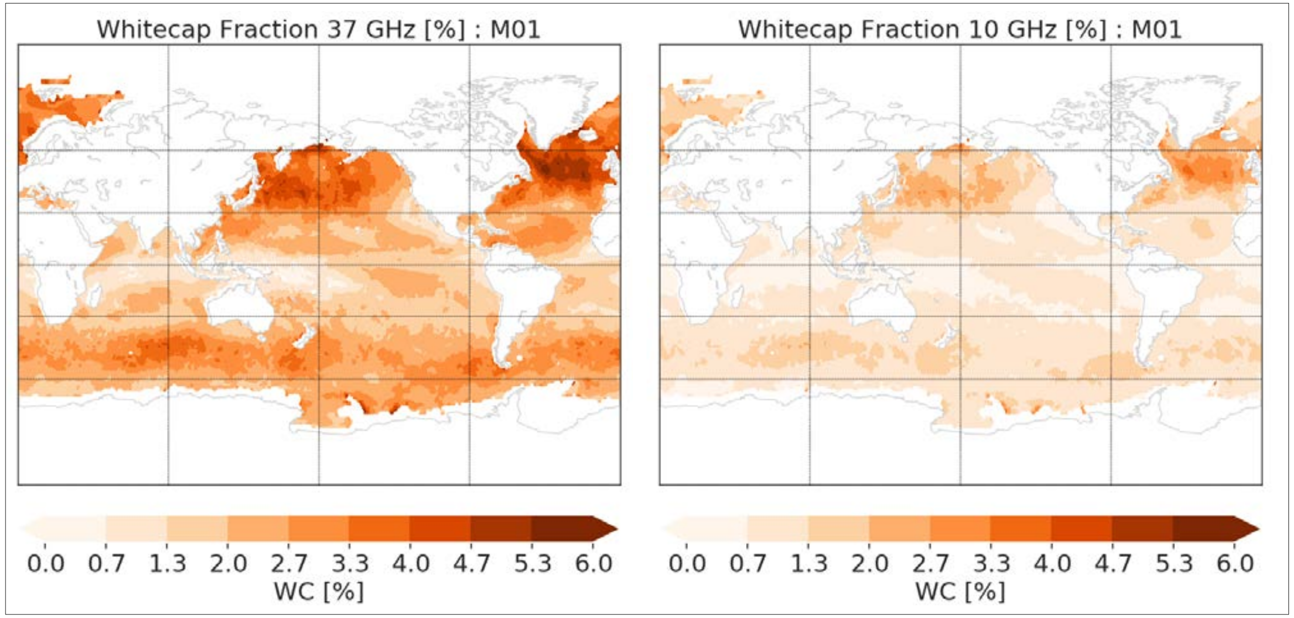
Including statistics of wind waves can help reduce the scatter in W

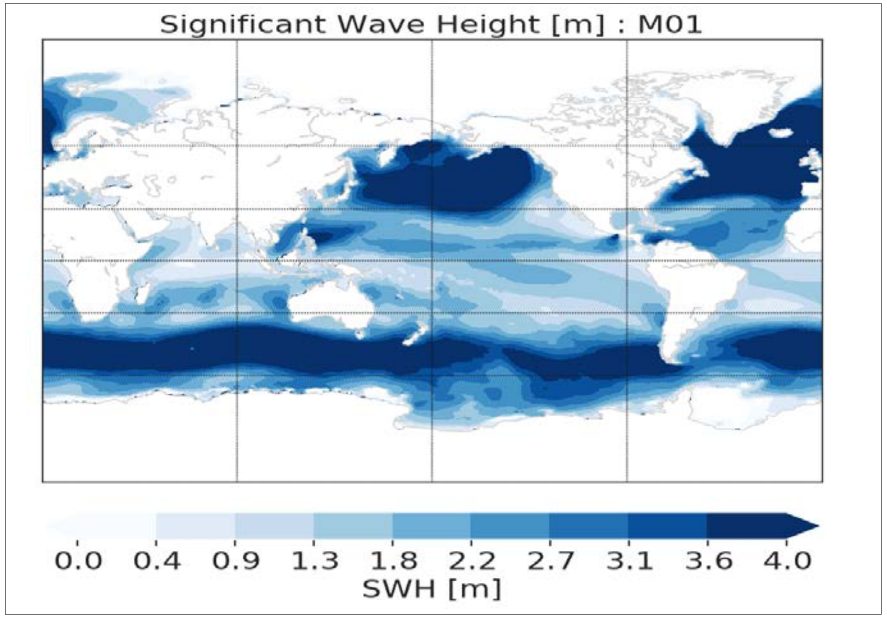
Objectives

- Test the utility of previously described whitecap parameterizations using NDBC measurements and NASA GMAO GEOS-UMWM model to understand the physical mechanisms driving whitecap fraction.

- Develop a **process based** whitecap parameterization for active and total whitecap based on Windsat whitecap retrievals at 10 and 37 GHz that is applicable globally.

Observation constrained modeling





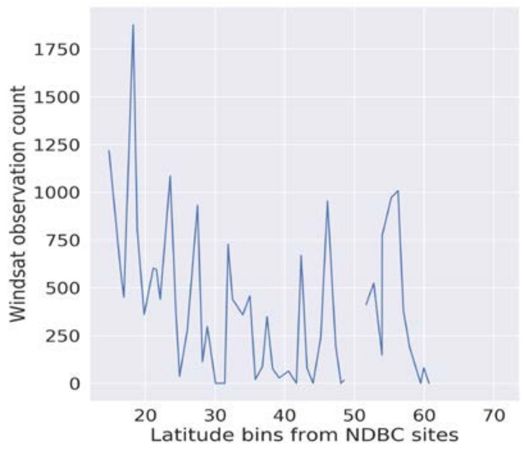
- Windsat W : 1° x 1° multi –frequency retrievals [Anguelova et al., 2019]
- 10 GHz includes more active W and 37 GHz include fresh + mature (foam) W

- GEOS-UMWM
  - 0.5° x 0.5° resolution runs for 2014 replayed to MERRA-2
  - Wind, sea-ice, air density input to UMWM from GEOS

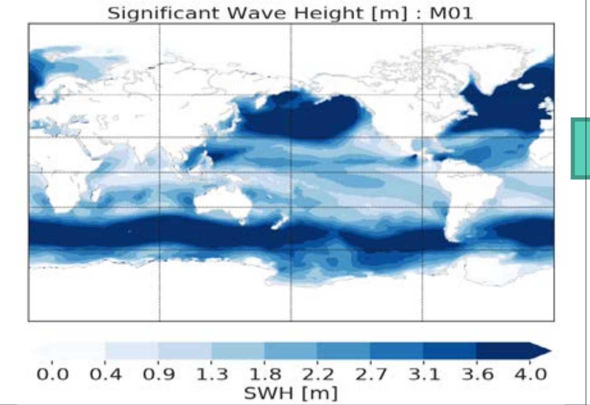
W parameterization development

NDBC Wind/wave collocated stations

Co-locate Windsat



Sample GEOS-UMWM at NDBC



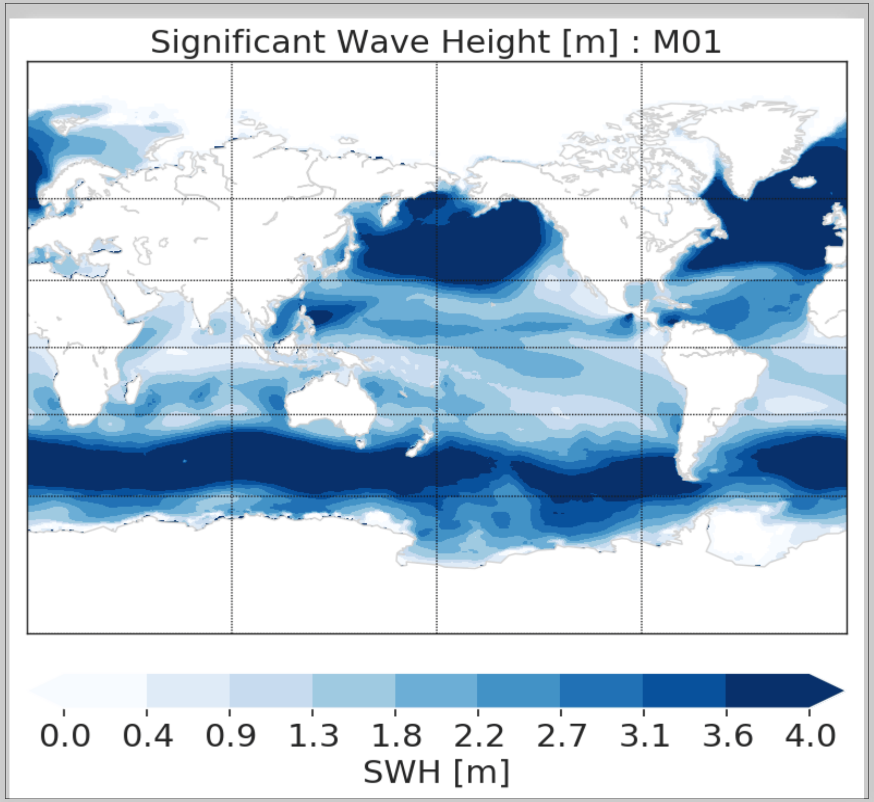
Model fitting

Steepness, Re, dissipation rate, peak period, peak, air-sea temperature difference, peak wave velocity

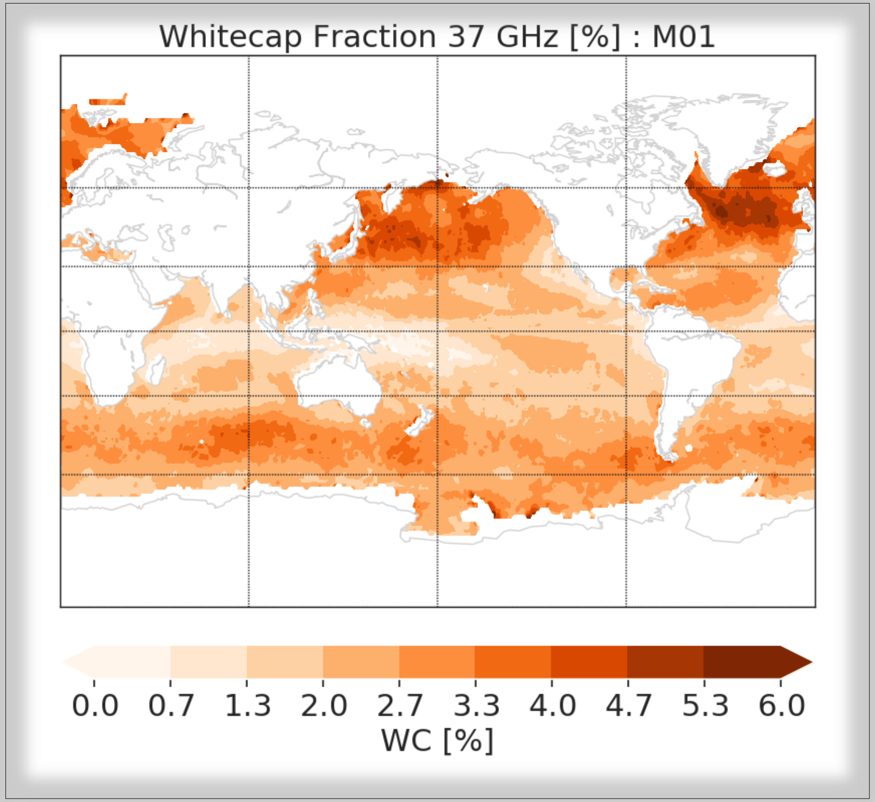
Test against independent Windsat W

W parameterization development (cont.)

GEOS Wind/Wave



Globally available Windsat W



Model fitting

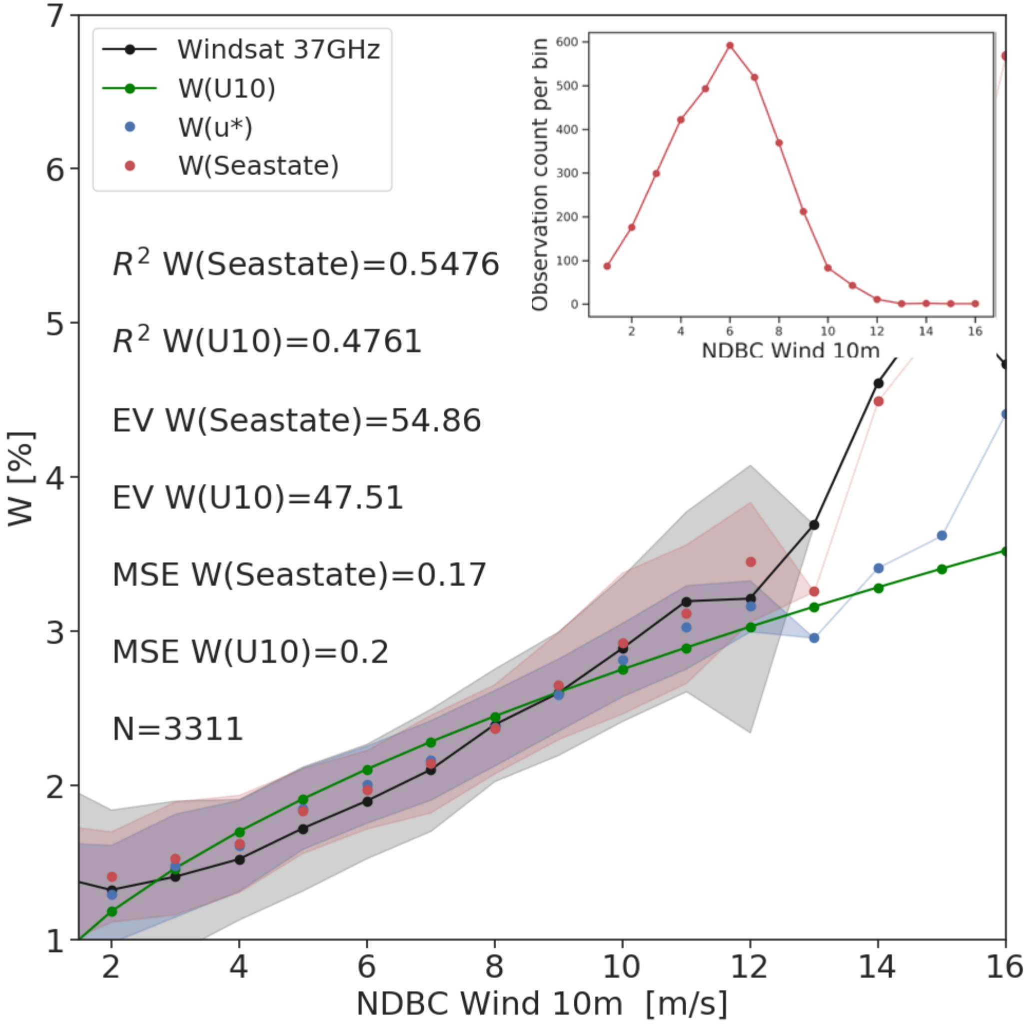
Coefficients f (wave field)

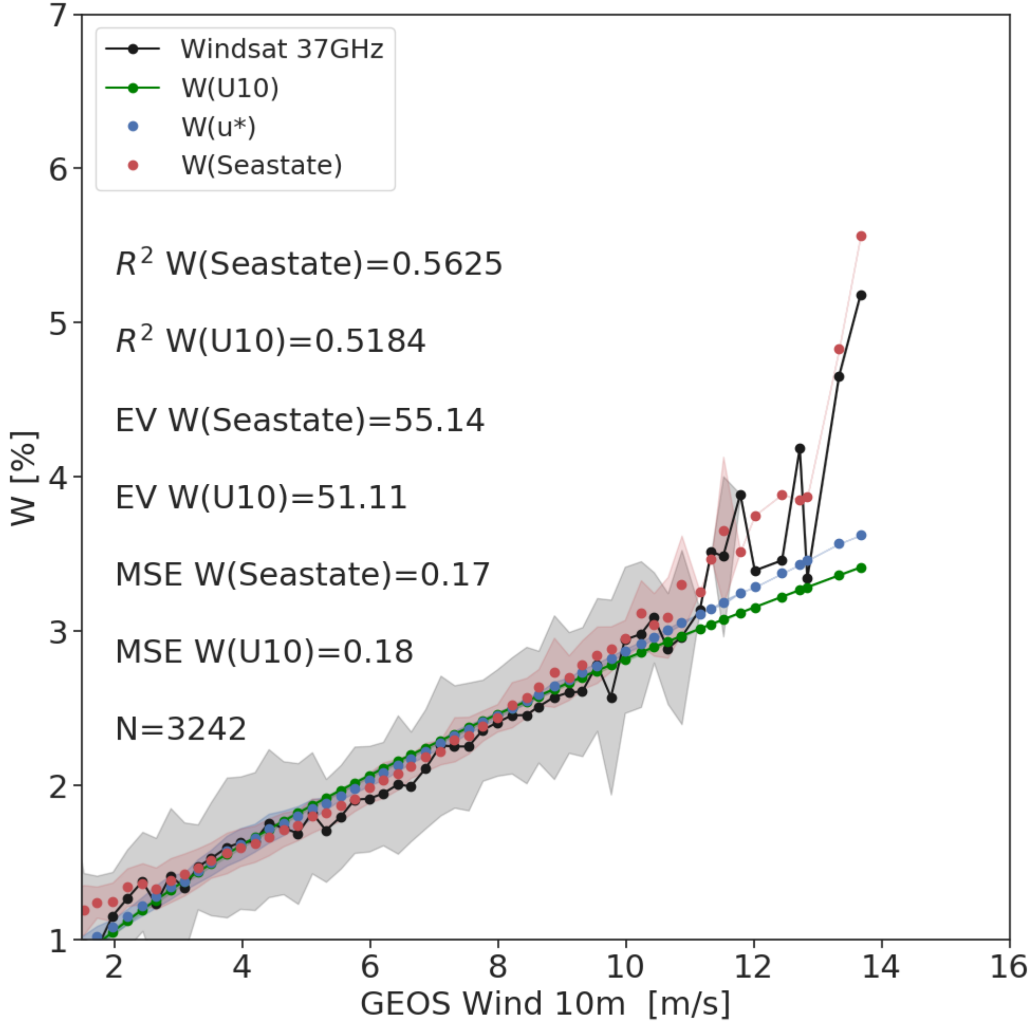
Add additional terms for high wind speed f (u)*

Test against independent Wind88t W

A. Raman and A. Darmenov

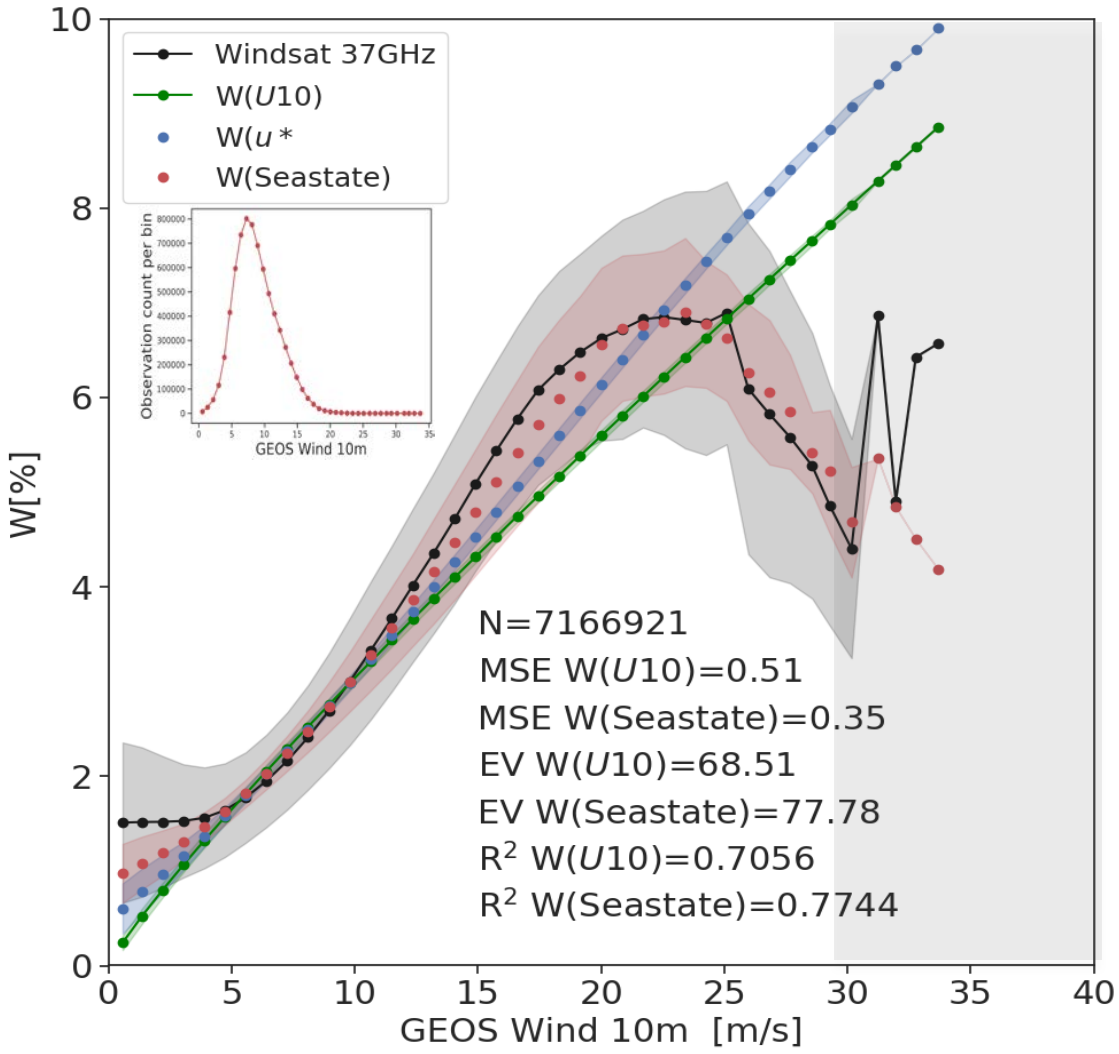
Variability with wind speed





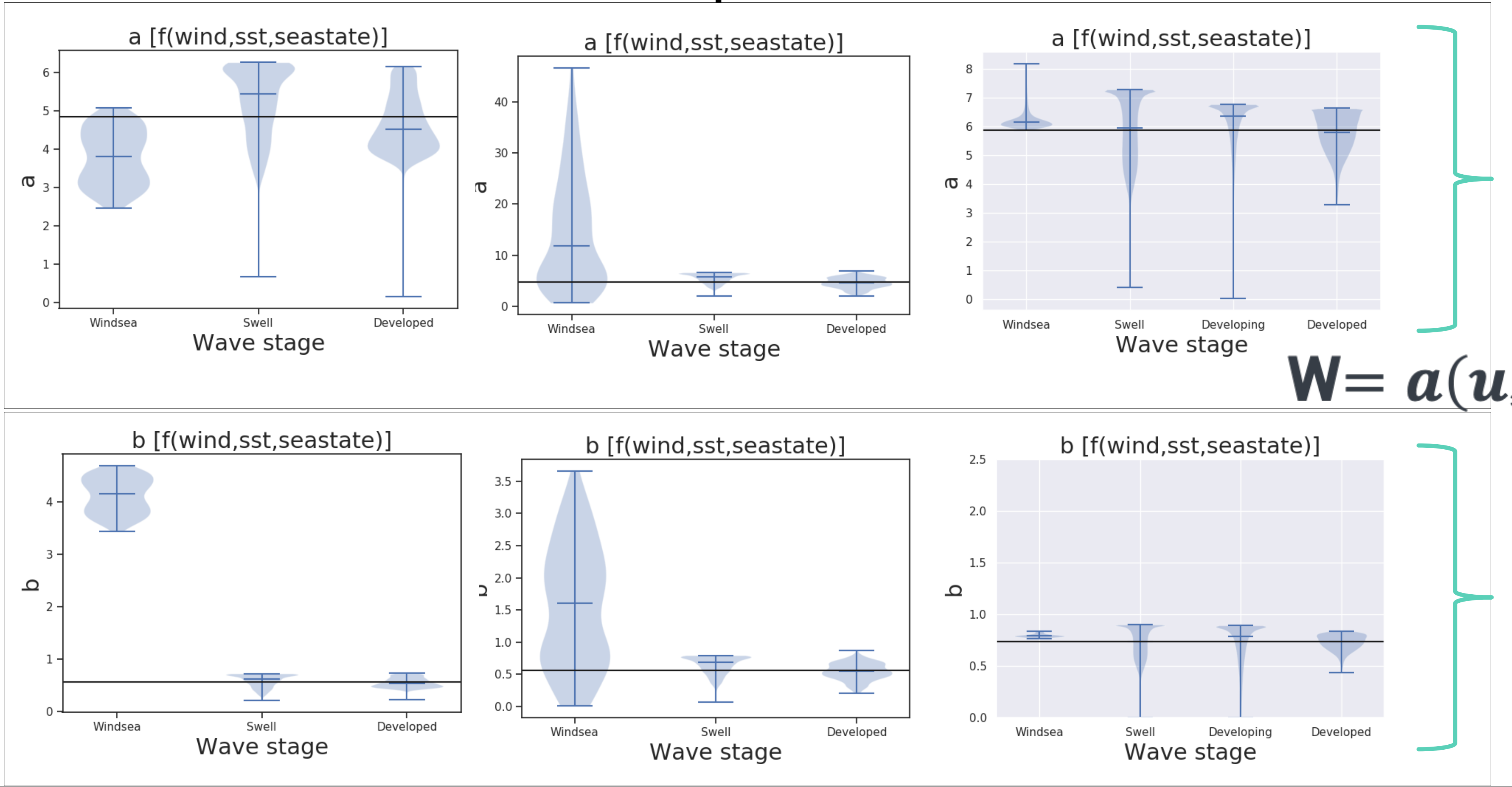
Variability with wind speed

- Whitecap decreases for higher windspeed.
- In order to capture this behavior in models, additional terms based on wind stress were added to the Seastate W model for wind speed > 20 m/s.



Variability in coefficients

NDBC | **GEOS sampled at NDBC** | **Global**

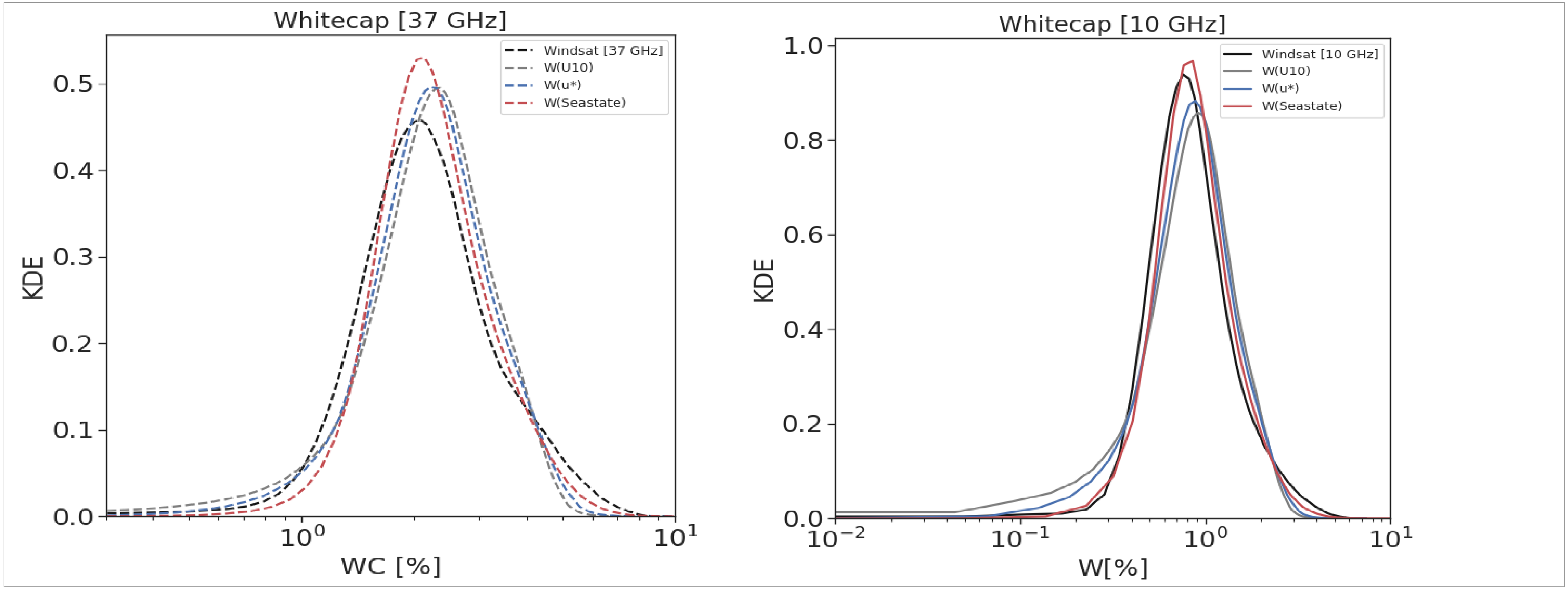


$$W = a(u_*)^b \, e^{(c\,\Delta T)}$$

Coefficient a

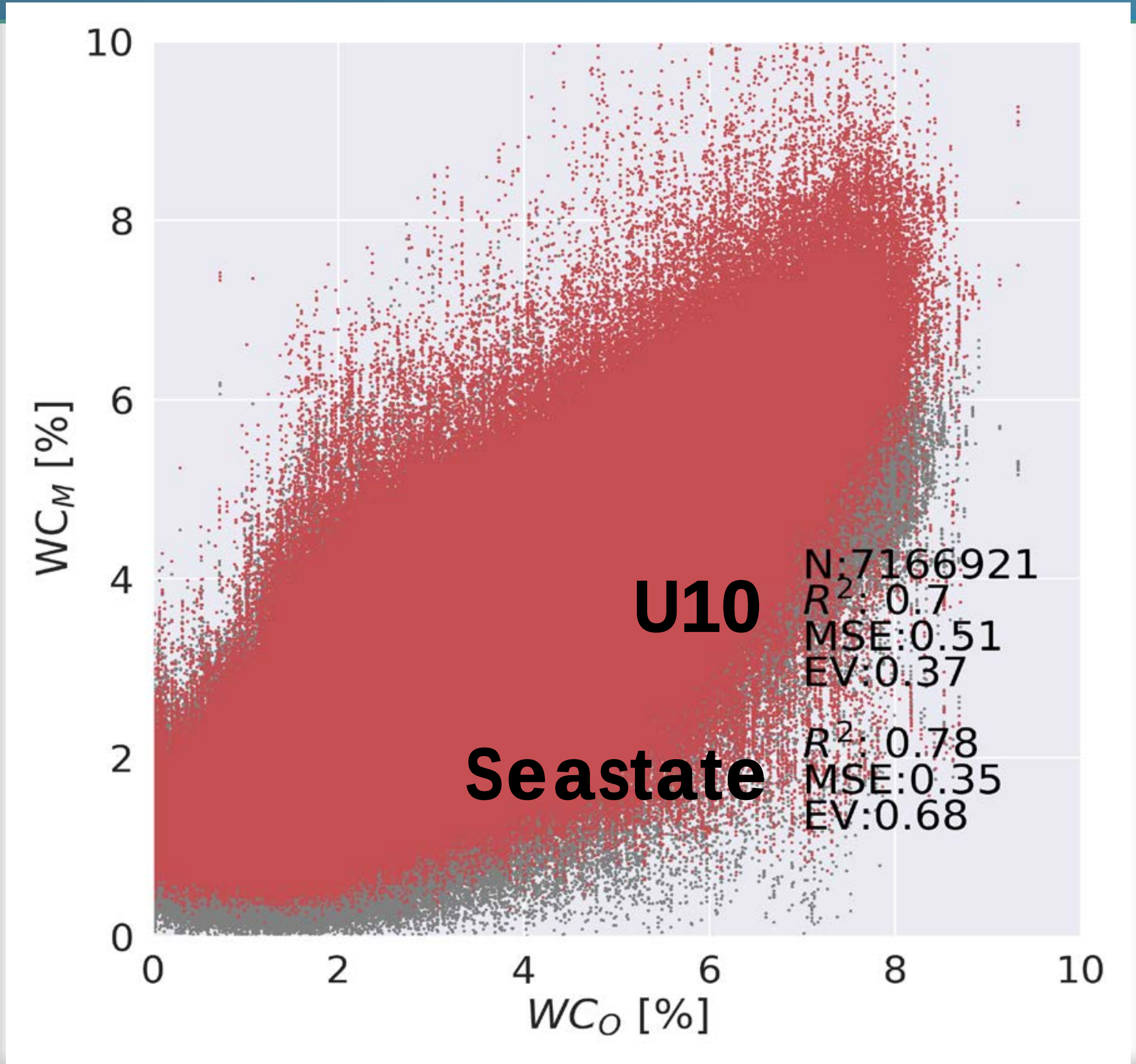
Coefficient b

Does inclusion of sea state improve W distribution?



- New parameterization improves the density of W for W < 0.1 % and W > 2%.
- Active whitecap responds to wave field inclusion better than total whitecap

Variability in Wmod (total W)



The proposed parameterization f(u*, ΔT, waves) when compared to the wind based parameterization showed improvements in MSE: 32% for swell and developed sea, 42% for windsea; all regimes - 31%

Significant spread in Wmodel remains unexplained!

Conclusions

- A physically motivated whitecap prediction model is developed using wind and wave fields from NDBC measurements and GEOS-UMWM wave model.
- Including wave field improves MSE (32% for total W ; 42% for active W) and explained variance for whitecap estimates for Swell and younger waves in comparison with Windsat.
- Active whitecap estimated using seastate based functions shows higher correlation and lower RMSE compared to total whitecap.

Future directions : Missing whitecaps

- Investigate scatter in seastate based whitecap models
  - Suspended particulate matter composition – organics, seaspray?
  - Bias in wave model friction velocity and drag?
- Use high resolution whitecap retrievals from Windsat
  - Sensitivity to reduced observation error
  - Sensitivity to high resolution geophysical variables.

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Thank you

Picture : ttps://www.surfertoday.com/surfing/surfers-enjoy-huge-swell-in-the-hawaiian-islands