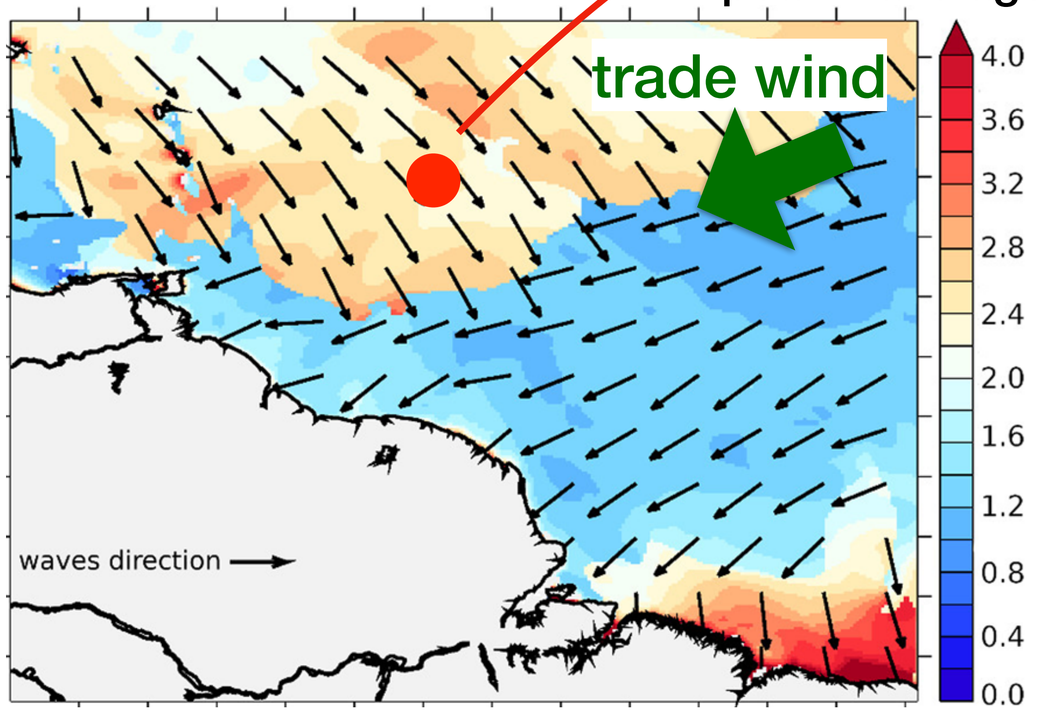
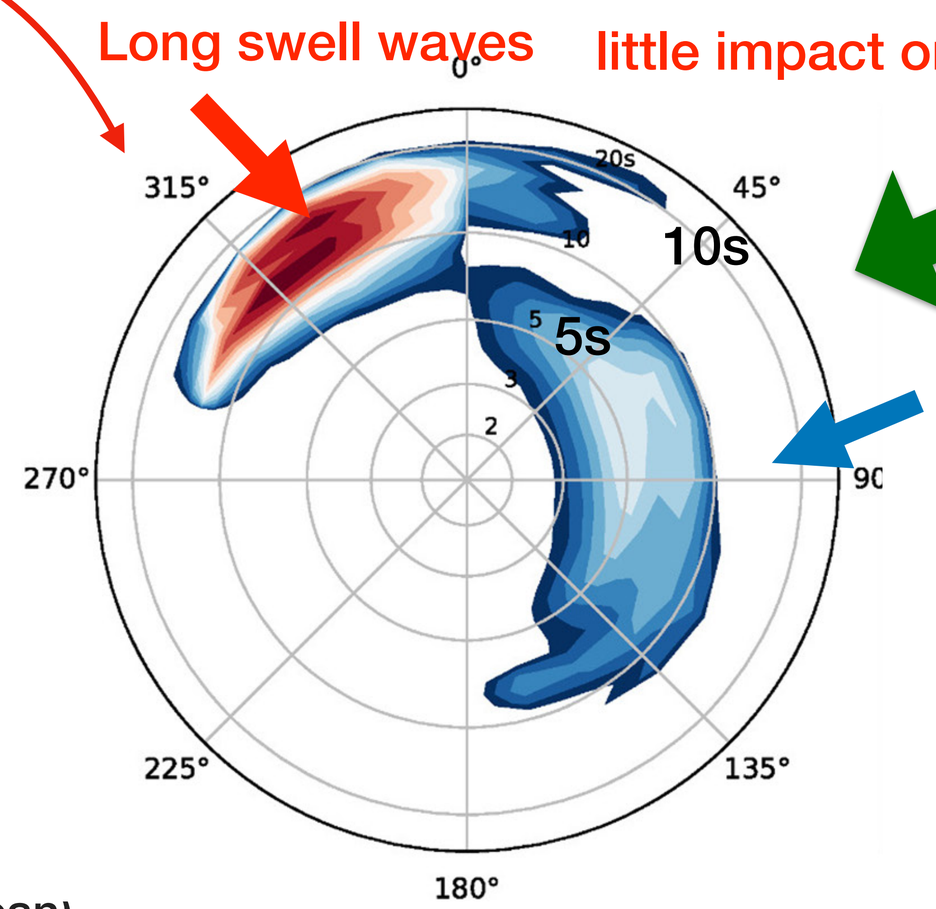
Wave-mediated air-sea flux parameterizations in mixed seas

Hyodae Seo, Sid Kerhalkar, César Sauvage, Amit Tandon

Air-sea momentum exchange is supported largely by the short wind waves, not by swell.

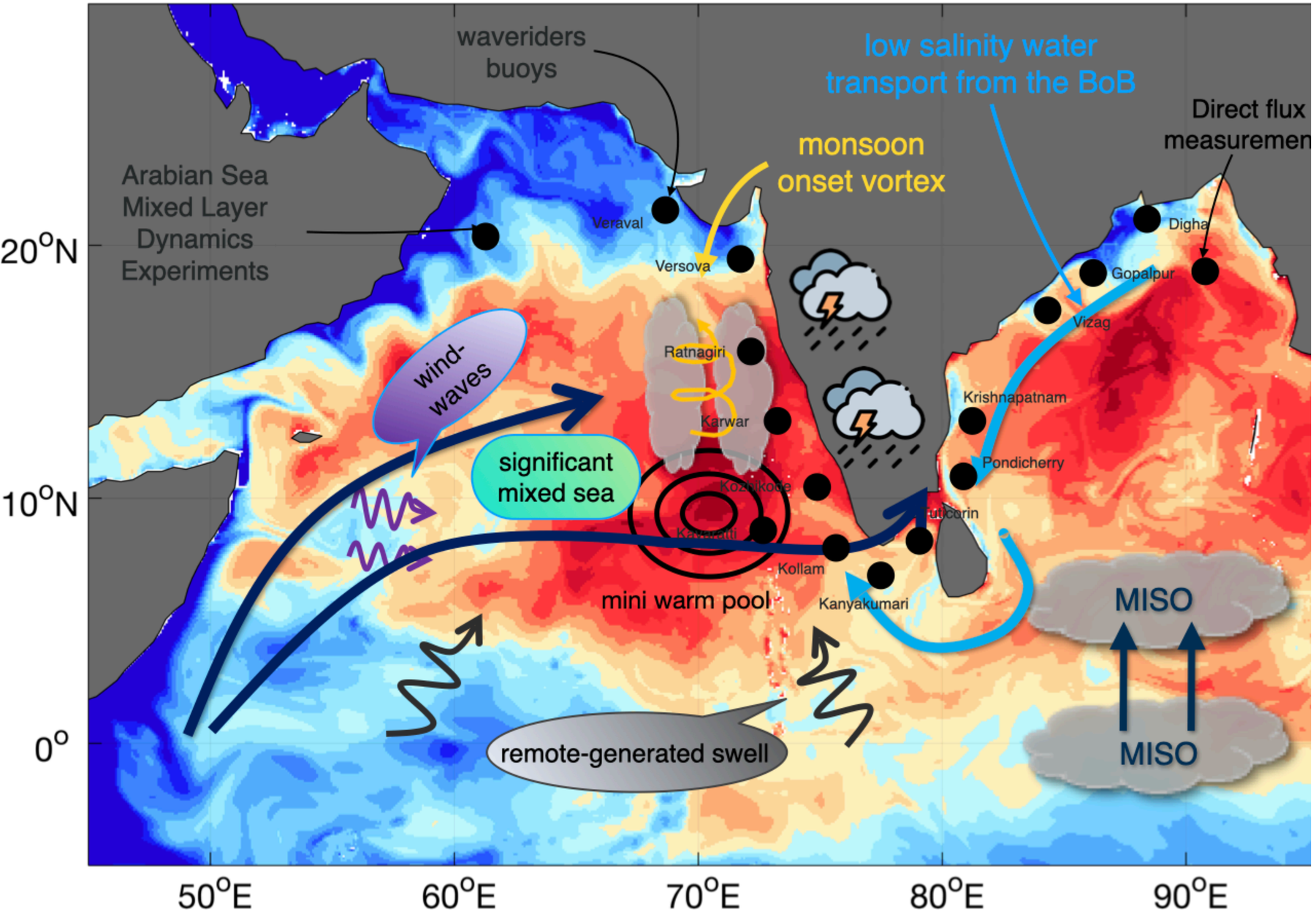
In boreal winter (ATOMIC)





Sauvage, Seo, Clayson and Edson (2023, JGR Ocean)

Late spring to early summer in Arabian Sea

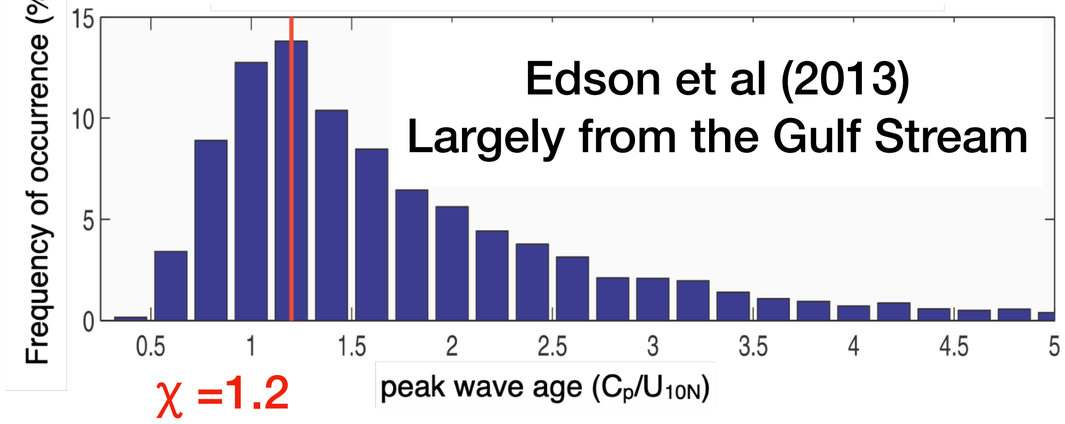


How should we parameterize the air-sea momentum flux in mixed seas?

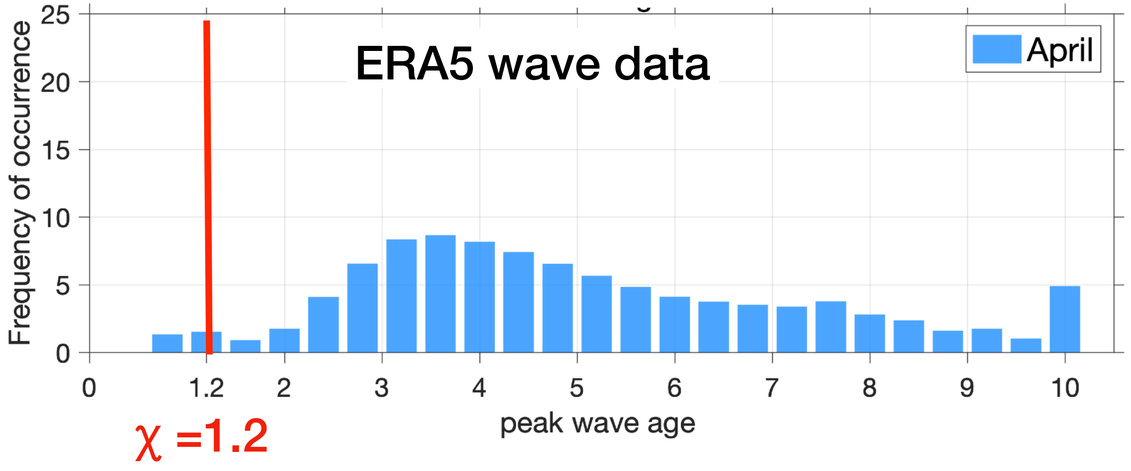
(Peak) Wave age

$\chi \equiv C_p/U_{10}$ (or C_p/u^*)

Peak wave age: COARE bulk flux algorithm

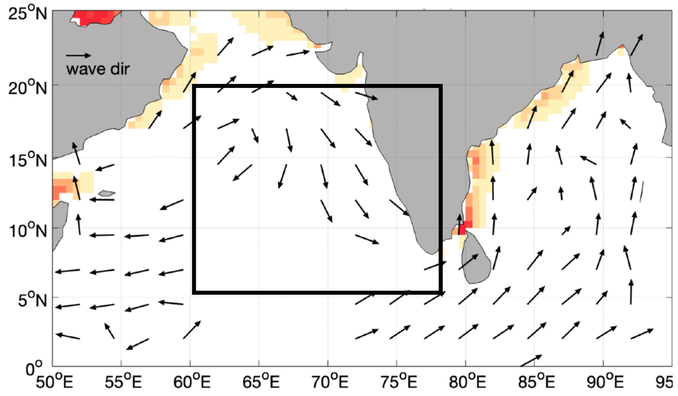


Peak wave age: Arabian Sea

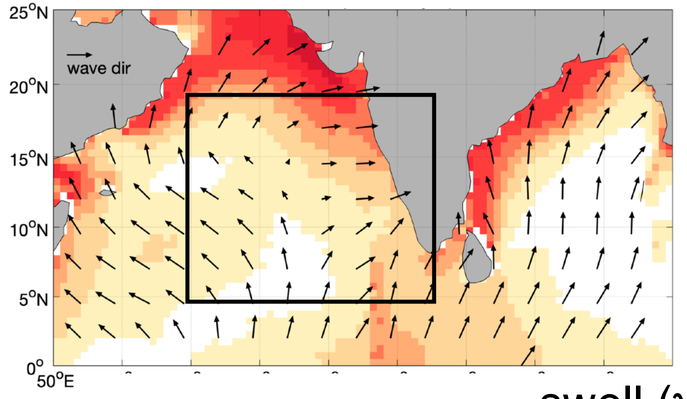


April

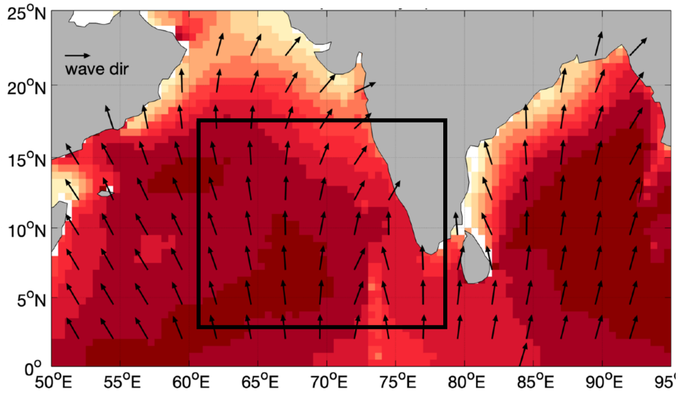
windsea (χ<1.2)



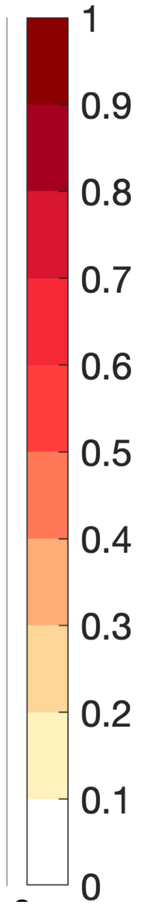
mixed sea (1.2<χ<3)



swell (χ>3)



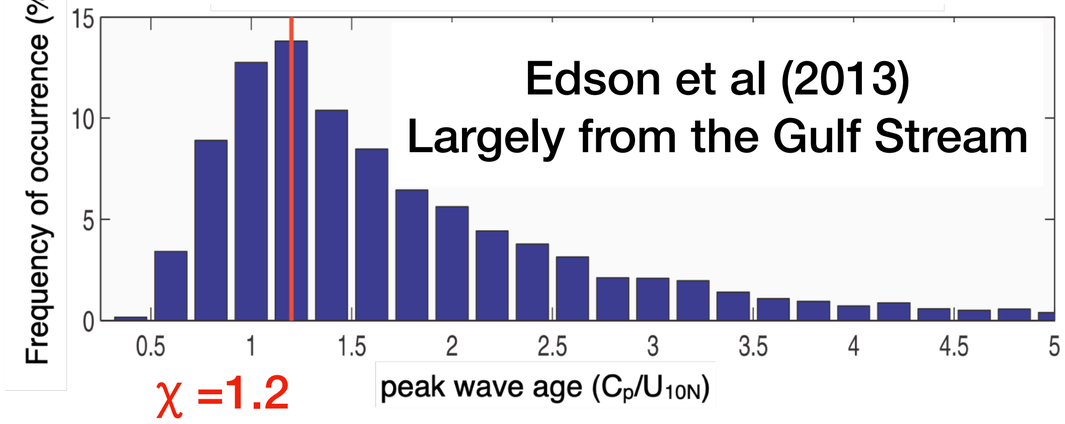
freq. occur



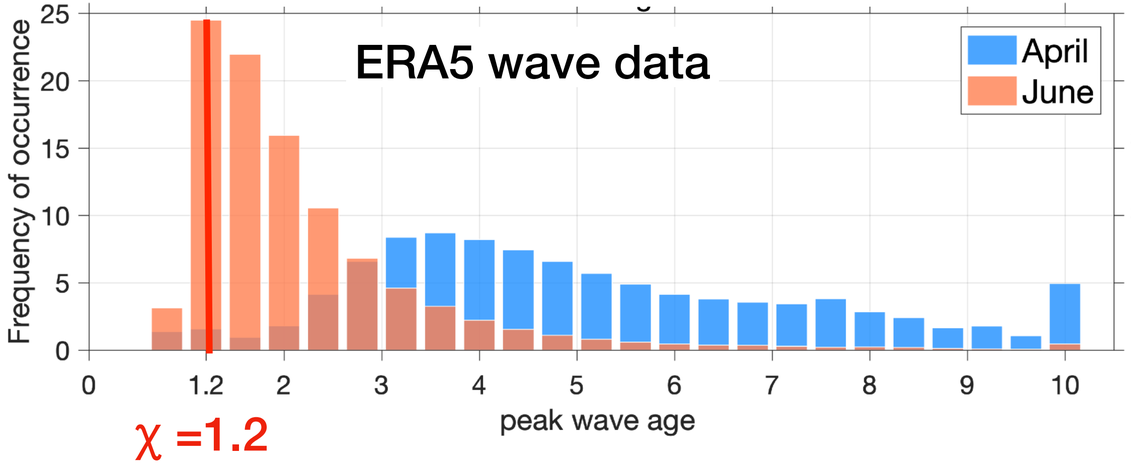
(Peak) Wave age

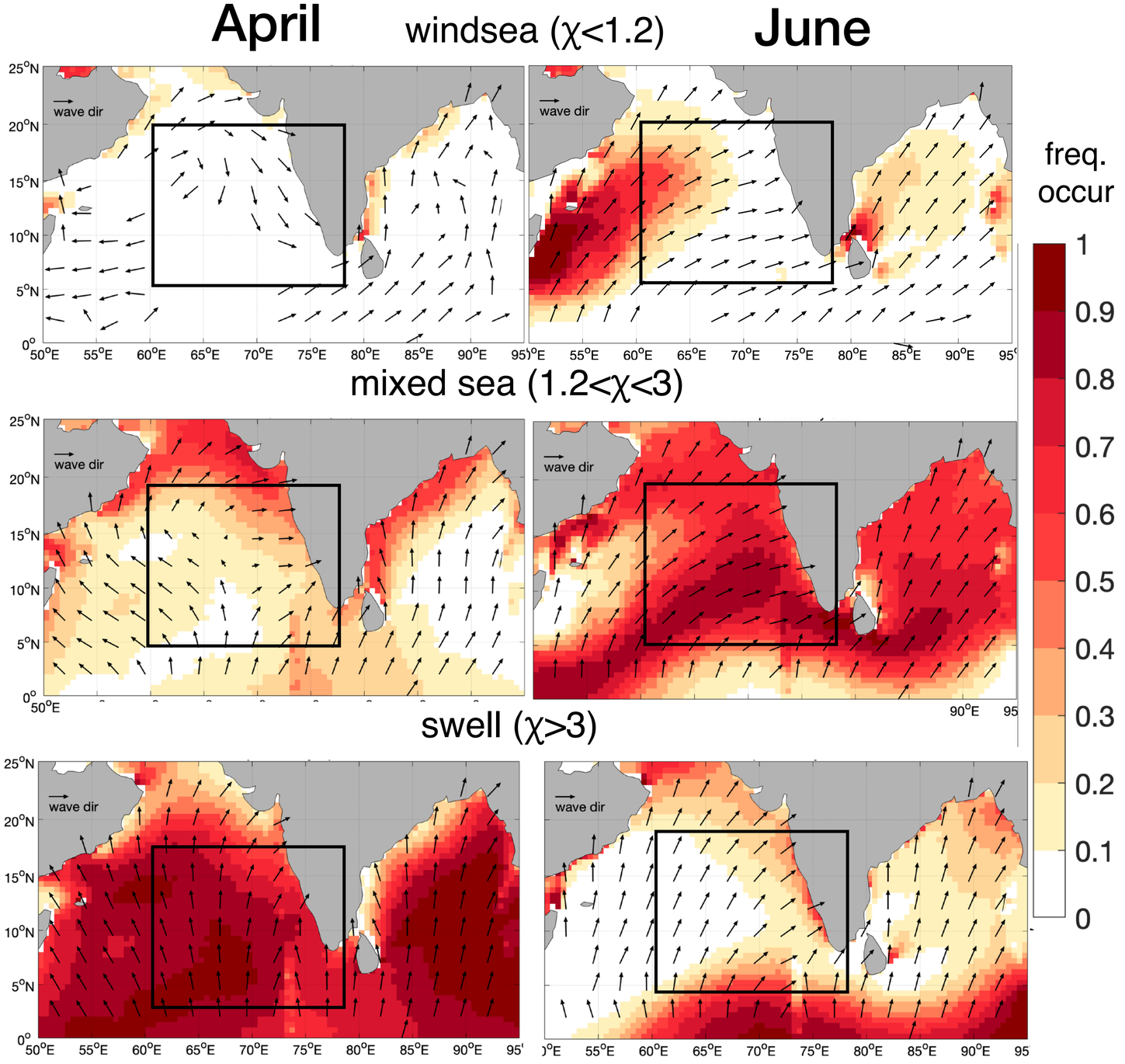
$\chi \equiv C_p/U_{10}$ (or C_p/u^*)

Peak wave age: COARE bulk flux algorithm



Peak wave age: Arabian Sea





How is surface roughness parameterized?

COARE algorithm (Edson et al. 2013)

$$\tau = \rho_a C_D U_r^2 \qquad C_D \cong \left[\frac{\kappa}{\ln(z/z_0) - \psi_m(z/L)}\right]^2 \qquad z_0 = z_0^{\text{smooth}} + z_0^{\text{rough}}$$

1. Wind Speed Dependent Formulation (WSDF)

$$z_0^{\text{rough}} = \alpha \frac{u_*^2}{g} \qquad \alpha = mU_{10N} + b$$

Charnock coefficient

- Assumes wind-wave equilibrium (χ~1.2)
- Assumes waves are aligned with winds (θ=0)
- Violated in mixed seas, as well as near strong density/vorticity fronts, shallow fetch-limited oceans, and rapidly translating cyclones

2. Wave-Based Formulation (WBF)

$$z_0^{\text{rough}} = H_s \cdot 0.09 \cdot \left(\frac{u_*}{C_p}\right)^2$$

significant wave height

inverse "peak" wave age

- The swell effect on surface drag is over-emphasized in mixed seas. The revised formulation:

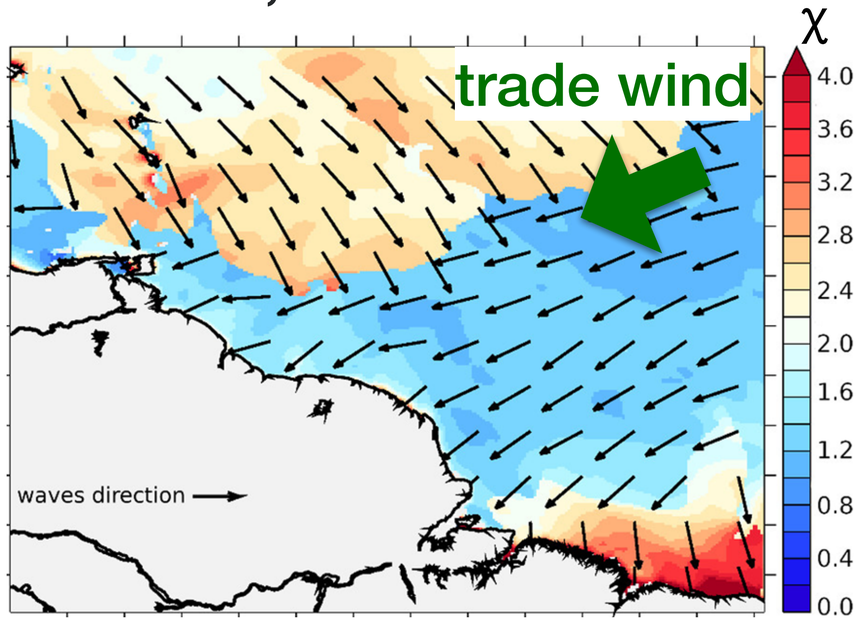
WBF_Cm $$z_0 = H_s \cdot 0.09 \cdot \left(\frac{u_*}{C_m}\right)^2$$

- Still assumes θ=0

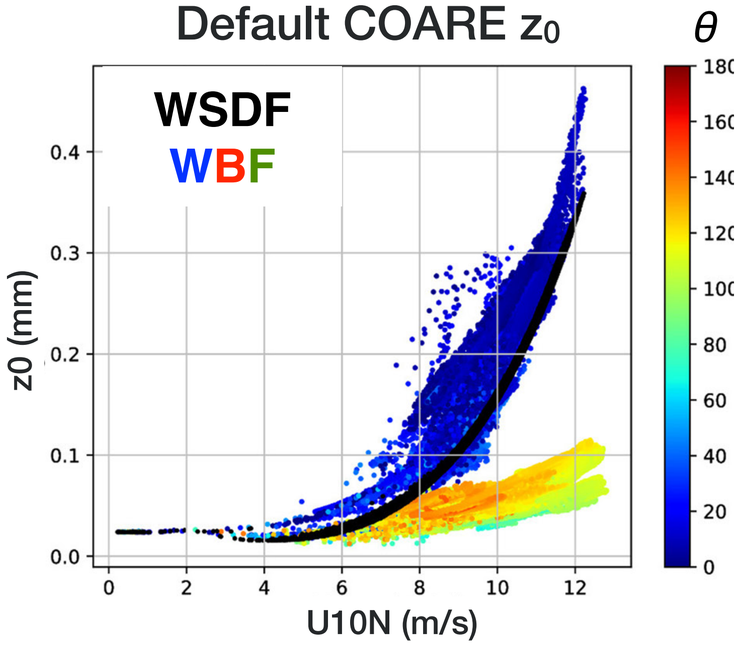
WBF_θ $$z_0 = H_s \cdot 0.09 \cdot \cos(0.45\,\theta) \cdot \left(\frac{u_*}{C_p}\right)^{2 \cdot \cos(-0.32\,\theta)}$$

ATOMIC, Jan-Feb 2020

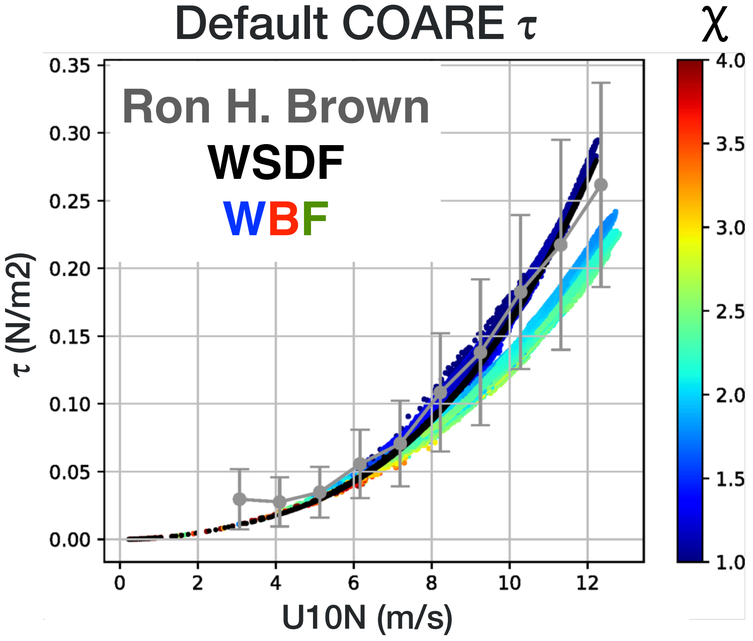
wave age & direction



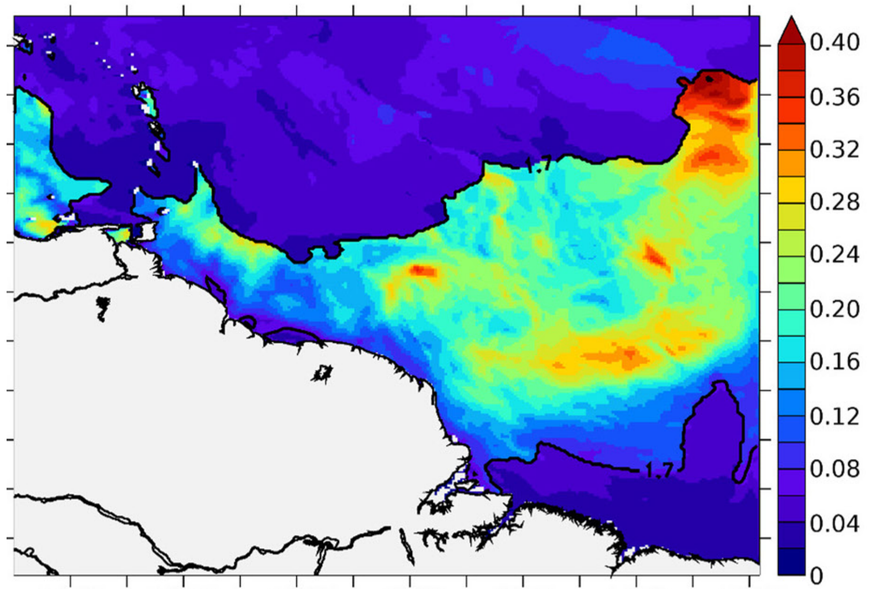
Default COARE z_0



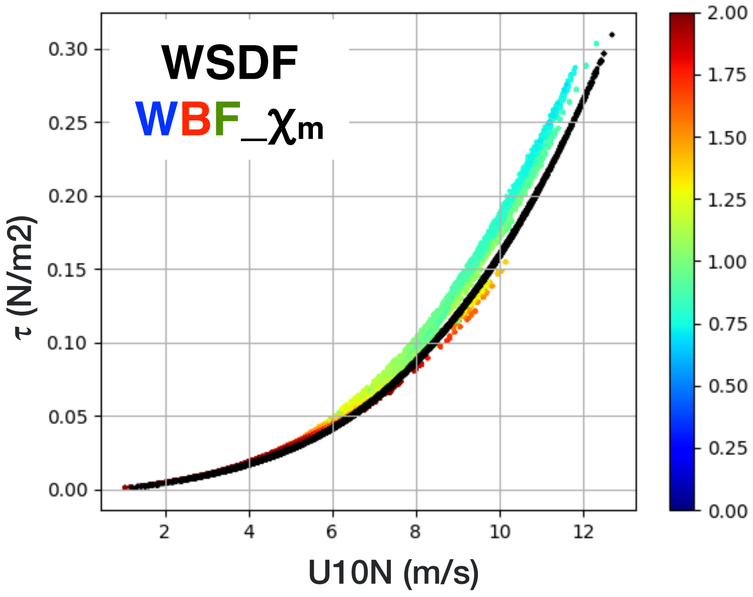
Default COARE τ



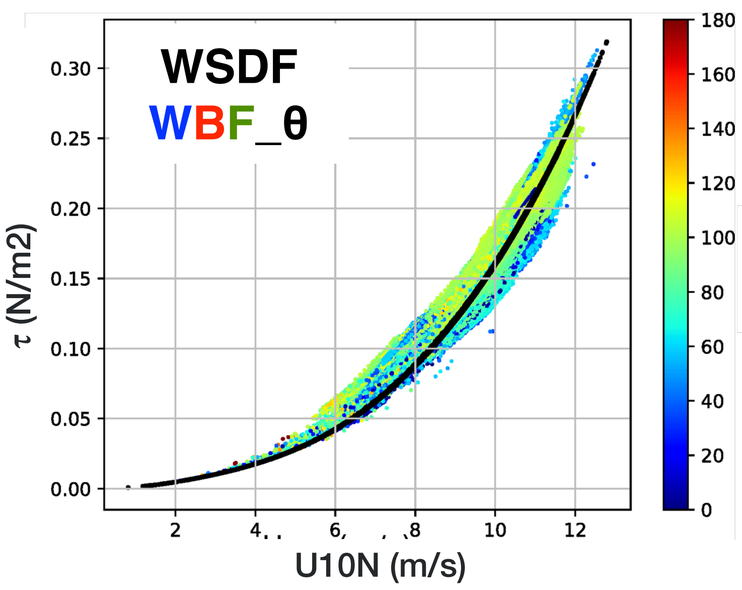
z_0 in WBF



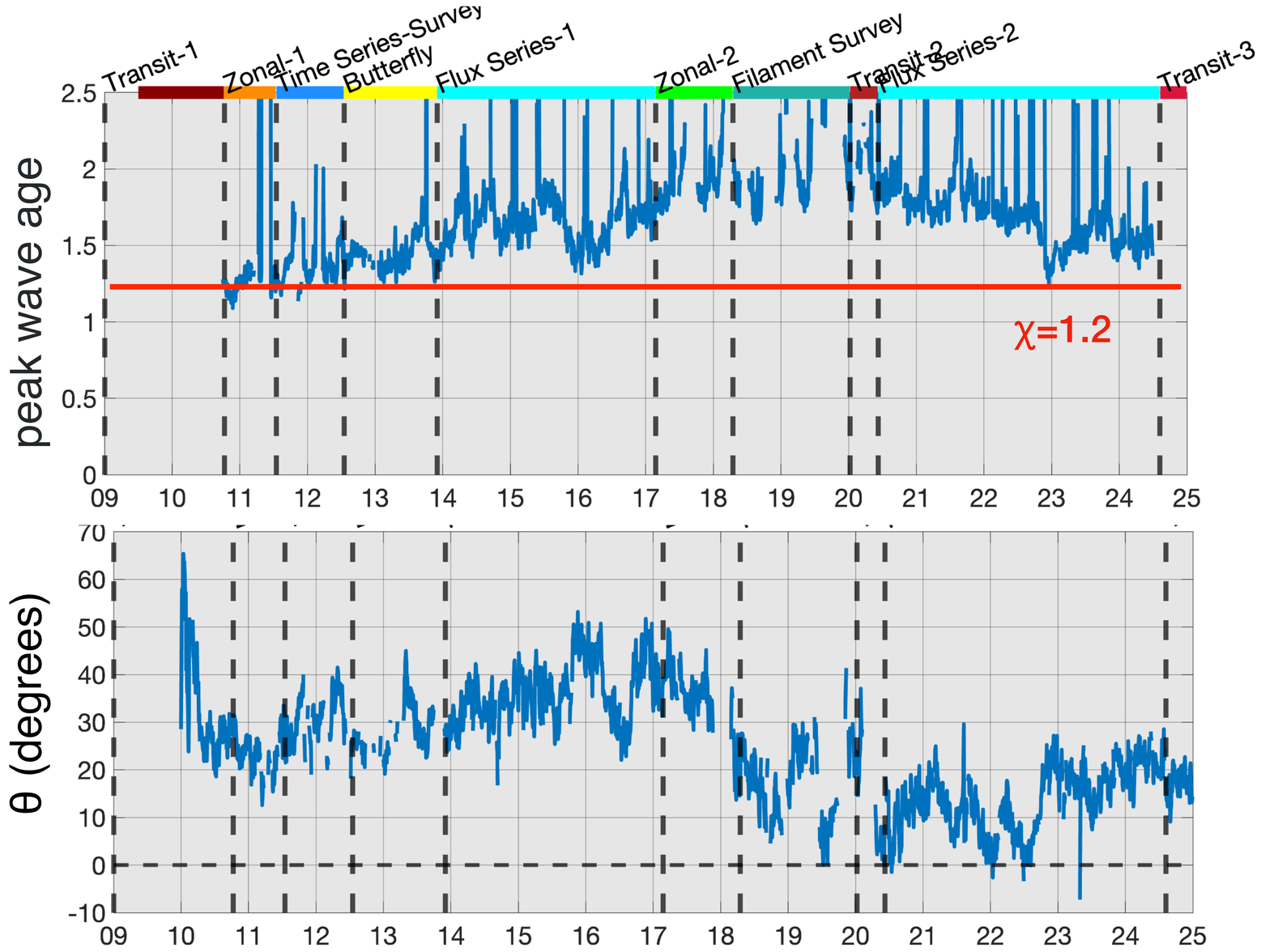
COARE with χ_m

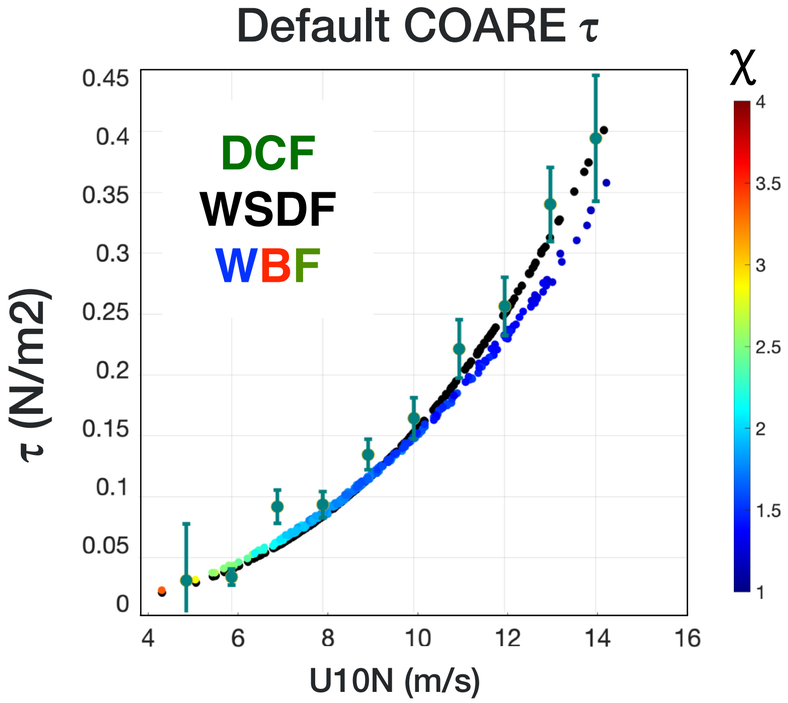


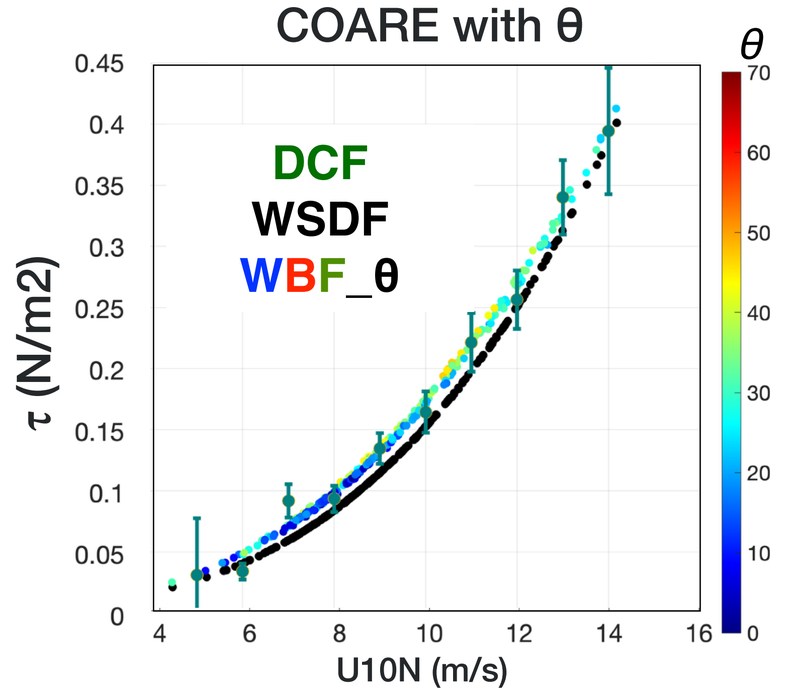
COARE with θ



EKAMSAT Pilot Cruise June 2023







Credits: Sid/Amit

Summary and Observational/Modeling Priorities

Air-sea momentum exchange is supported largely by the short wind waves, not by swell.

By using peak wave information and ignoring the misaligned wave effect, the COARE wave-based formulation underestimates the surface drag and wind stress in mixed seas.

- (Variously) Revised formulations exist and are being offered in the SCOAR model
- Many coefficients must be determined using very limited (regionally-biased) datasets.
- Regional refinement or regime-specific tuning of the formulations is needed.

Observational Priority:

- Need longer-term DCF and directional wave measurements.
- Leverage existing and future time series (BoB INCOIS, DYNAMO, OOI arrays, and TPOS).

Modeling Priority:

- The formulations should be accurately incorporated / tested in numerical models.
  - Spatial variability of the fluxes
  - Impacts on simulation skills