The pdf of Sea Surface Winds: Effects of Variable Stratification and Boundary Layer Height

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Probability distribution of sea surface winds: Why do we care?

- *Surface Exchange*

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- This talk will consider influence of variable surface stratification and boundary layer thickness on the wind speed pdf

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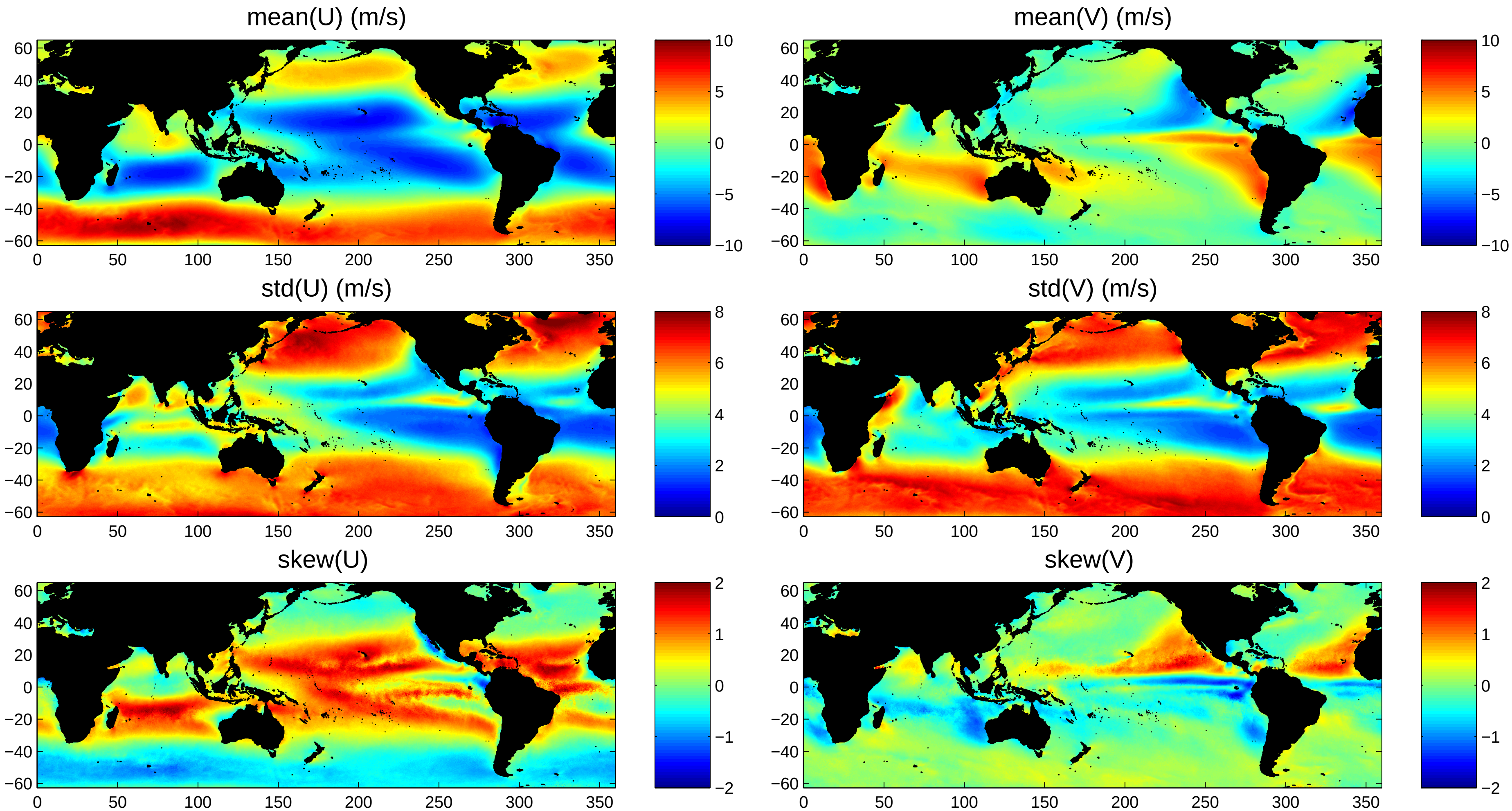
Vector Wind Moments



Zonal Wind

Meridional Wind

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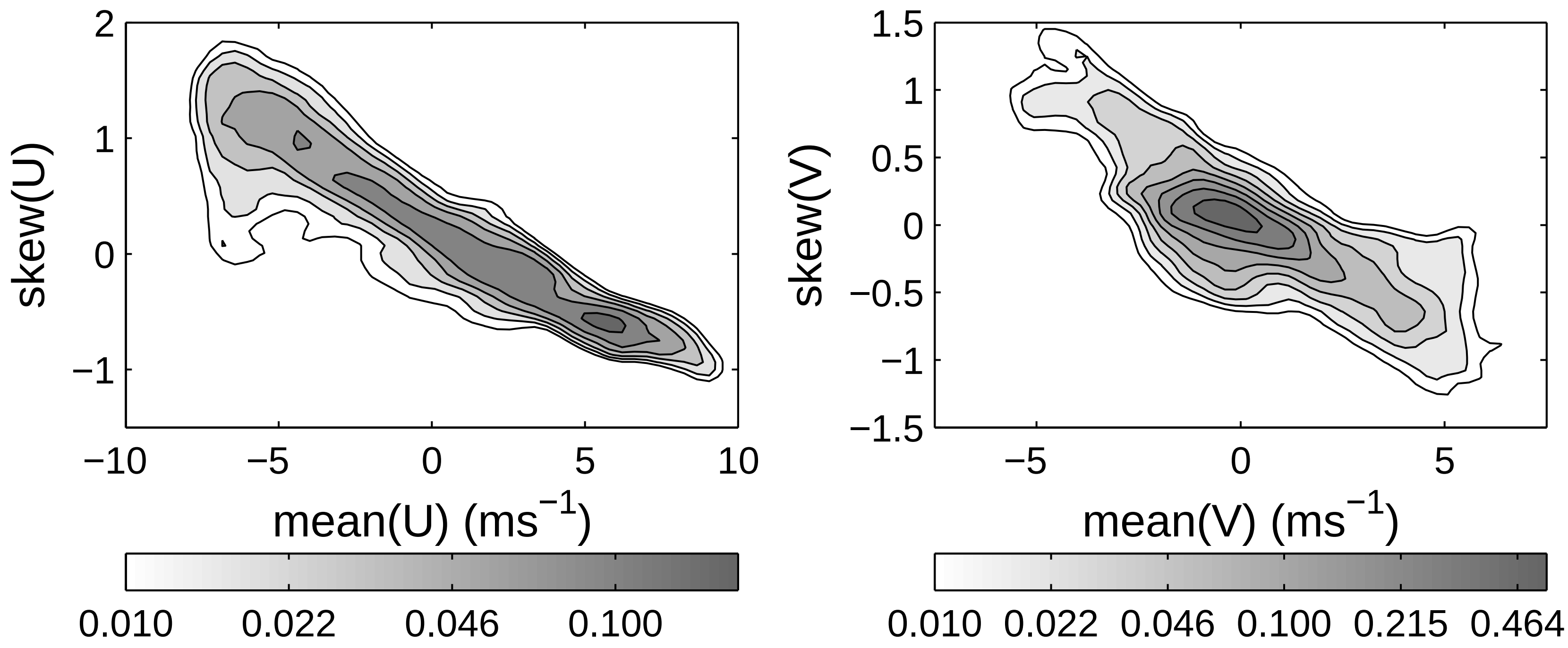
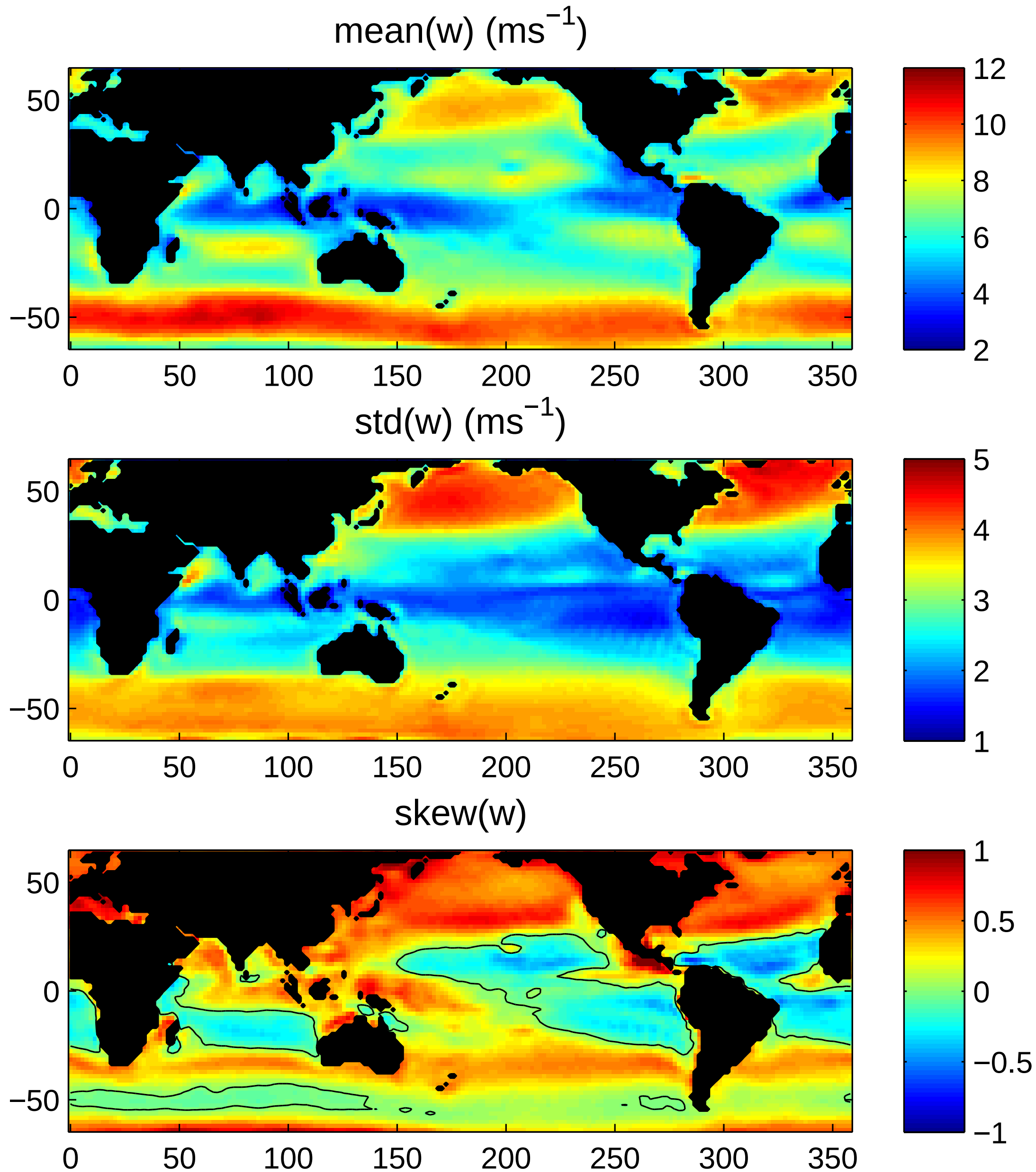
Mean and Skewness of Vector Wind

- Joint pdfs of mean and skew for zonal and meridional winds



Wind Speed Moments



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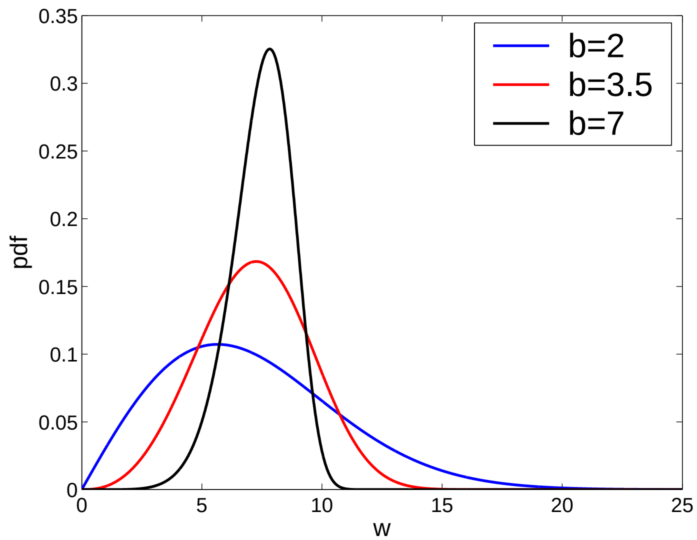
Wind Speed pdf: Weibull distribution

- The pdf of wind speed w has traditionally (and empirically) been represented by 2-parameter Weibull distribution:



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\begin{aligned}
p(w) &= \frac{b}{a}\left(\frac{w}{a}\right)^{b-1}\exp\left[-\left(\frac{w}{a}\right)^{b}\right] \\
\text{skew}(w) &= S(b) \\
b &\simeq \text{mean}(w)/\text{std}(w)
\end{aligned}
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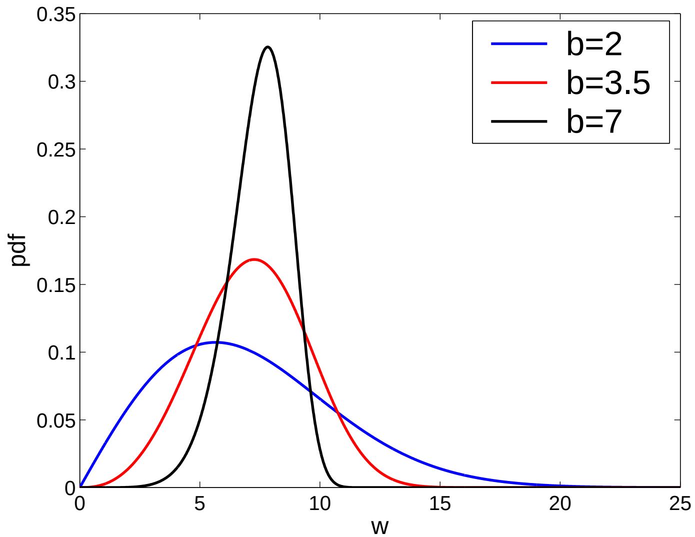

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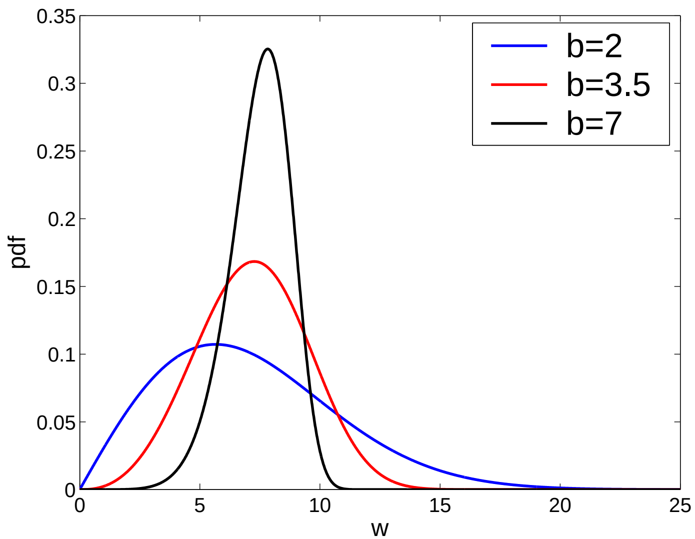

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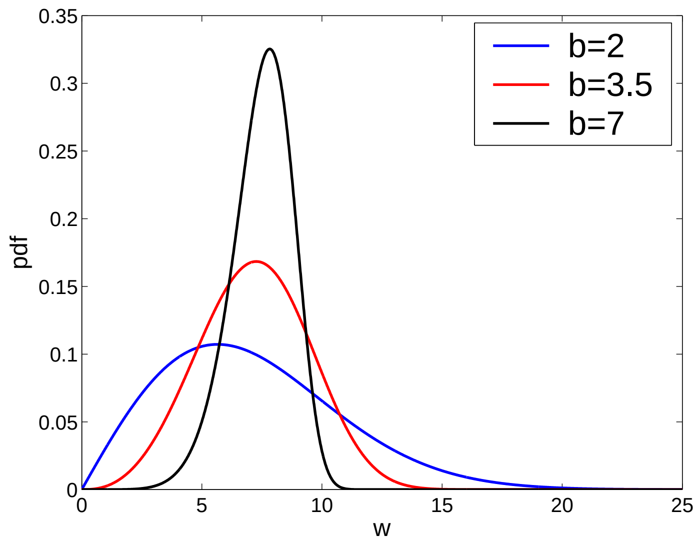

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- $p_w(w)$ is unimodal

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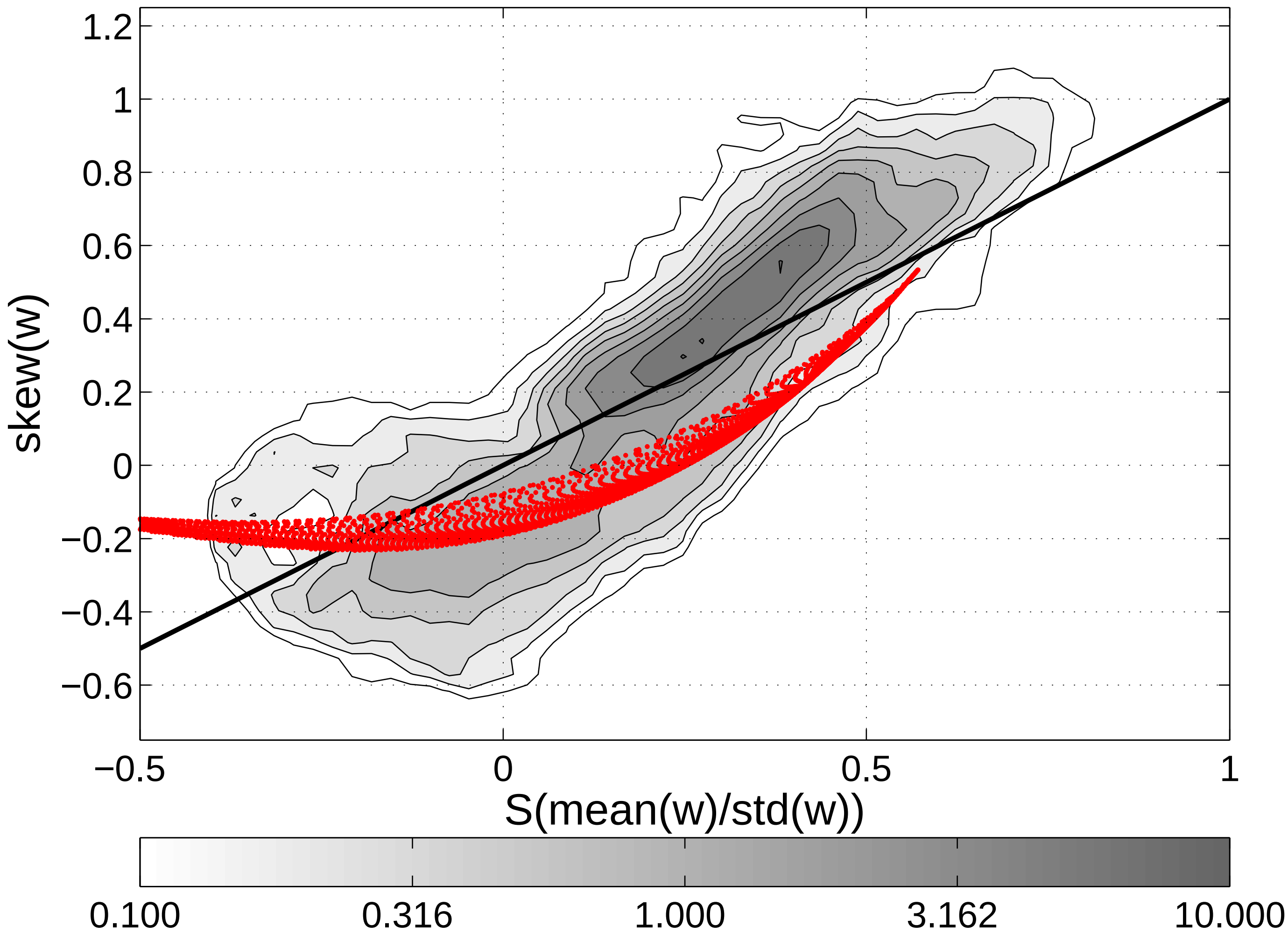
Wind speed pdfs: observed and modelled



Black line: Weibull , Red dots: idealised BL momentum budget model

Notation

$$
\begin{aligned}
u &= \text{along-mean wind component} \\
v &= \text{cross-mean wind component} \\
\mathbf{u} &= (u, v) \\
w &= \text{wind speed} \\
h &= \text{boundary layer depth} \\
T &= \text{SAT-SST}
\end{aligned}
$$

Wind speed pdfs: mechanisms

- Mechanistic model of $p(w)$ based on boundary layer momentum budget

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  - surface drag (nonlinear)
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  - “ageostrophic forcing" (mean and fluctuating)
- Momentum budget averaged over BL (neglecting horiz. advection)

$$
\begin{aligned}
\frac{du}{dt} &= \overbrace{\frac{\overline{U}_s}{\tau_s}}^{\mathbf{A}} + \overbrace{\frac{\eta_u}{\tau_s}}^{\mathbf{B}} - \overbrace{\frac{c_d(w,T)}{h}wu}^{\mathbf{C}} + \overbrace{\frac{w_e}{h}(U(h+\delta)-u)}^{\mathbf{D}} + \overbrace{\sigma_u \dot{W}_1}^{\mathbf{E}} \\
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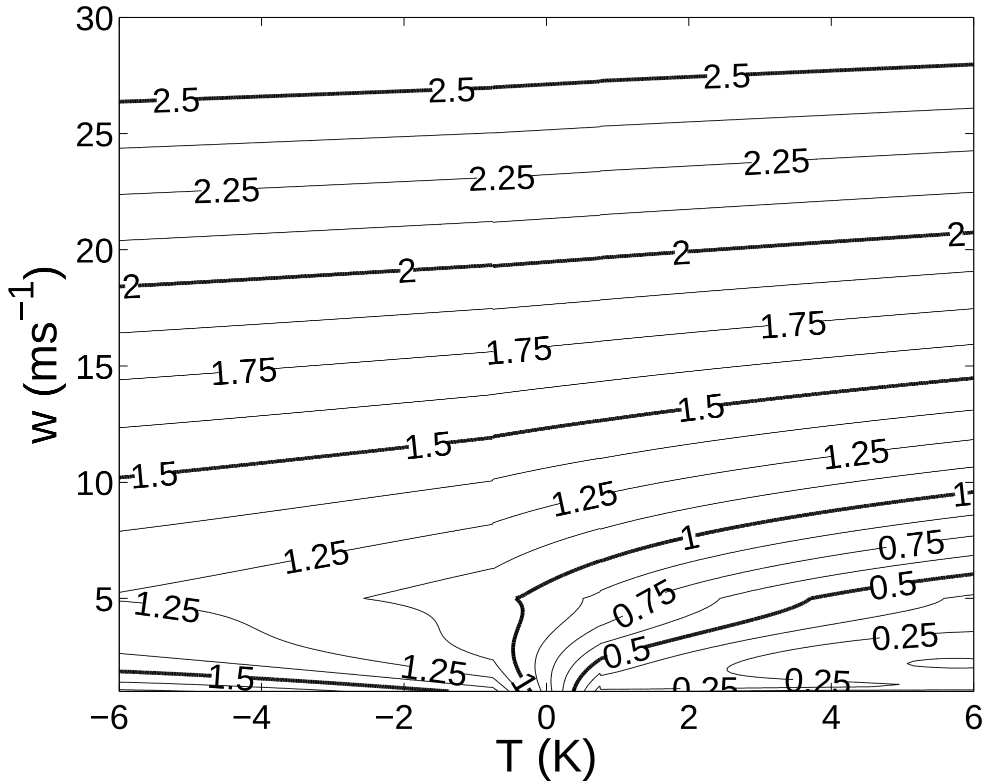

COARE Parameterisation

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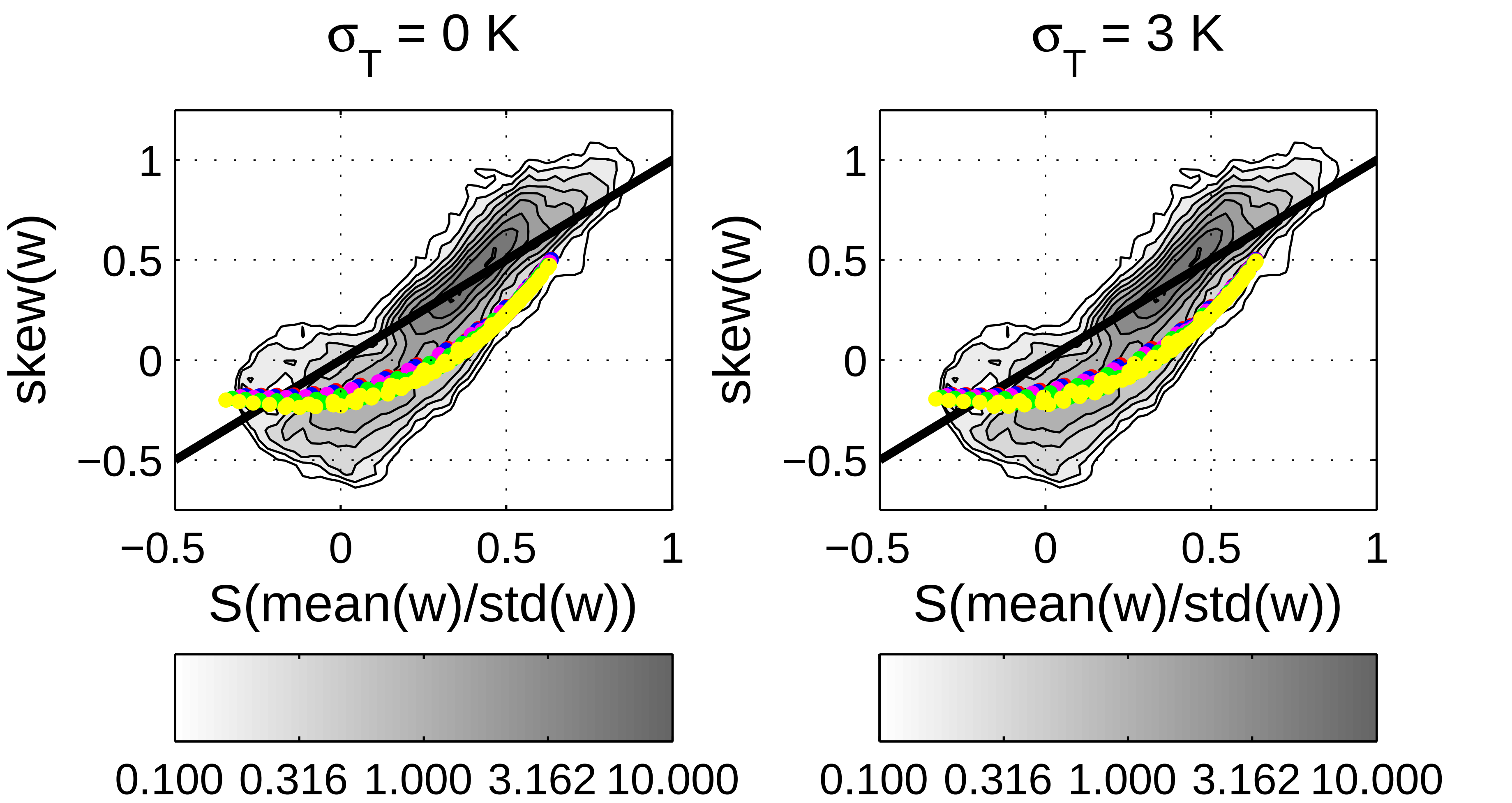

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Wind stress - SST coupling: observations

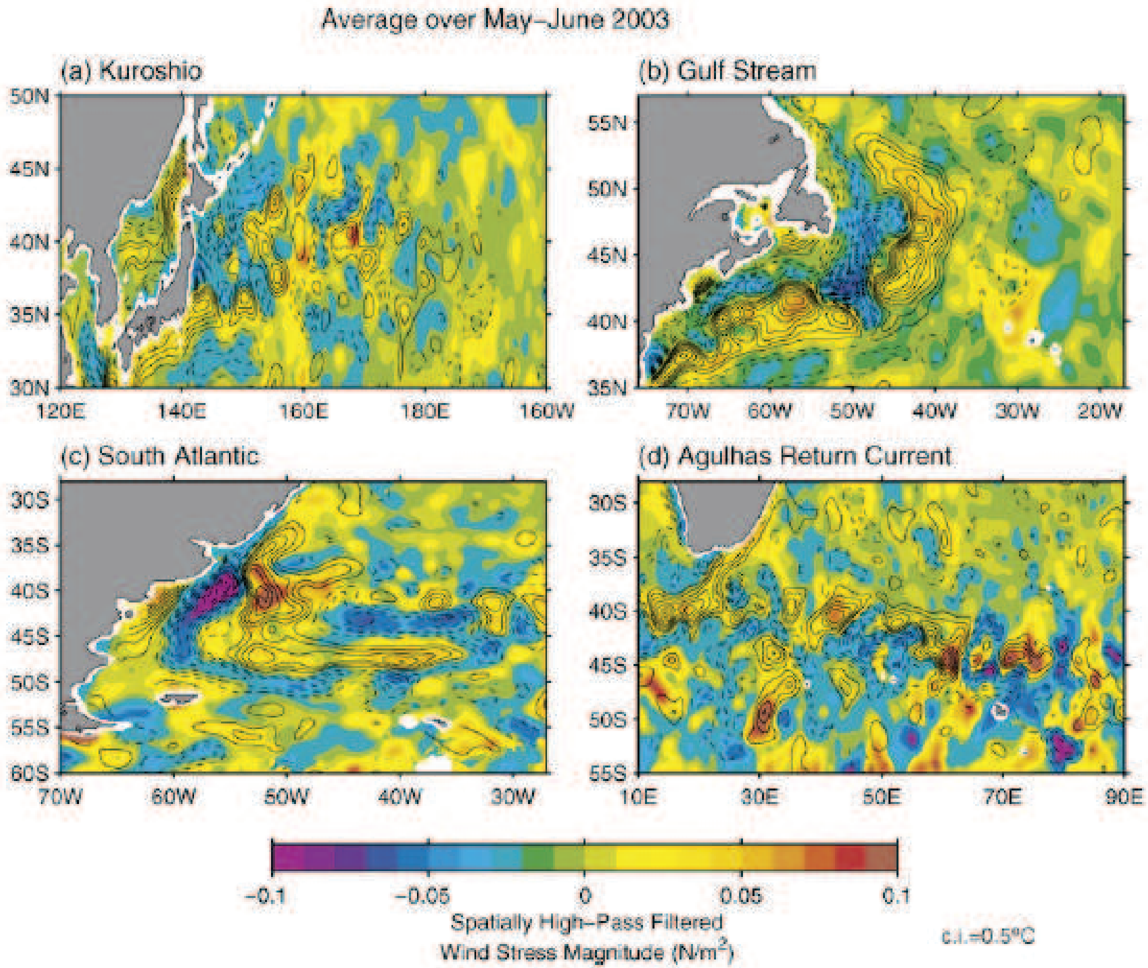

Fig. 2. Maps of spatially high-pass filtered 2 months (May–June 2003) average wind stress magnitude (N m^{-2}, color) and SST (°C, contours, interval 0.5 °C, zero contour omitted). Data from QuikSCAT scatterometer and AMSR-E. (a) North-west Pacific, Kuroshio region, (b) North-west Atlantic, Gulf Stream and North Atlantic Current region, (c) South-west Atlantic, Brazil-Malvinas confluence, and (d) Southern Indian Ocean, Agulhas Return Current.

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Warm SST $\Rightarrow$ *faster* winds (e.g. Small et al., Dyn. Atmos. Oceans, 2008)

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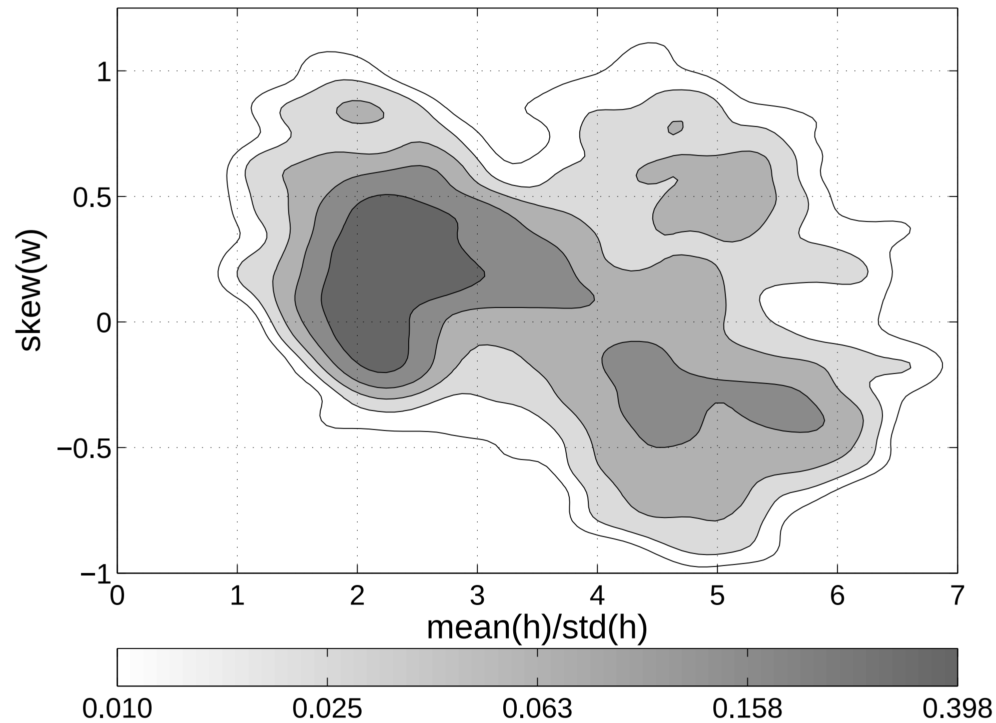

From ERA-40 Reanalysis

BL variability: idealised model

- Simple model of BL variability

$$\frac{d}{dt}h = -\frac{1}{\tau_h}h + w_e^* + \frac{\zeta}{\tau_h}$$

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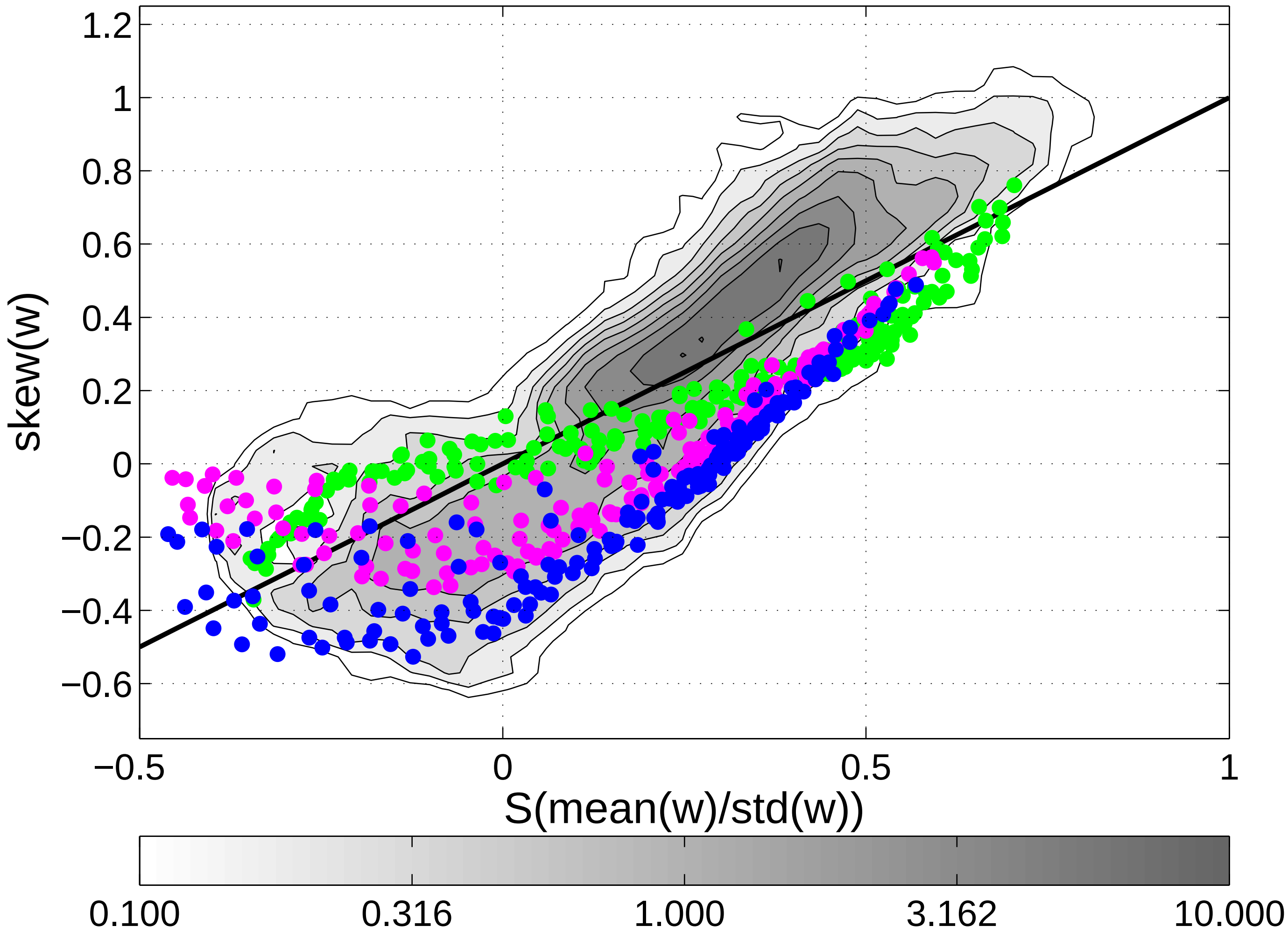
- “Large-scale" winds equal $\mathbf{u}$ in BL

$$\mathbf{U}(z,t) = \mathbf{u}(t) \quad z < h$$

and relax toward specified shear in free atmosphere

$$\frac{\partial}{\partial t}\mathbf{U}(z,t) = \frac{1}{\tau_{env}}(\mathbf{U}_s + \mathbf{\Lambda}z - \mathbf{U}) \quad z > h$$

Wind speed pdf: variable BL effects



std(h) = 0 m (blue), 200 m (magenta), 400m (green)

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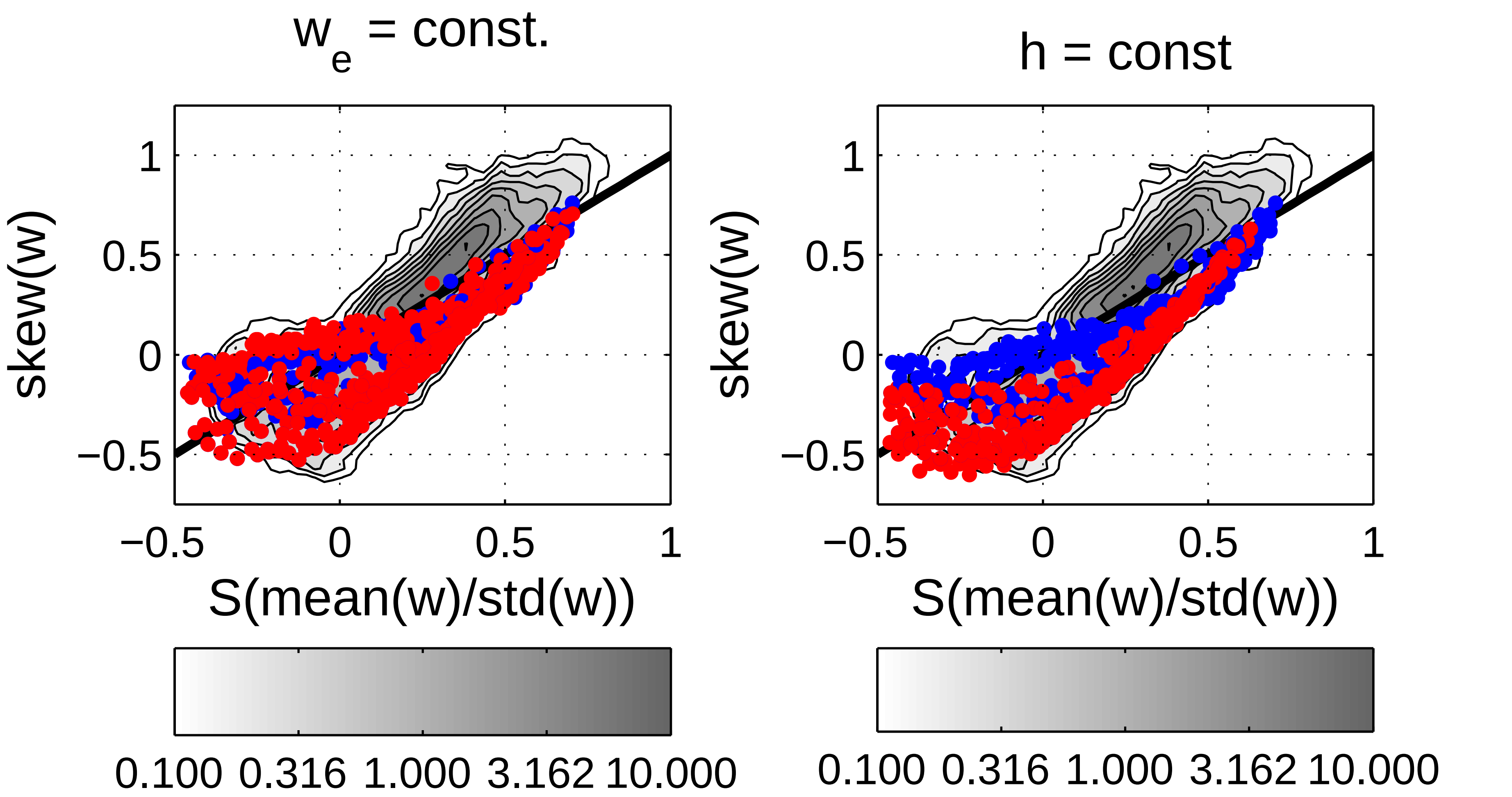

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- Need for more complex BL model; goal of future research

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