The Physical and Aerodynamic Roughness of Sea Ice

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Parameterize Turbulent Surface Flux

Momentum Flux:

\[ \tau \equiv -\rho \overline{uw} = \rho u_*^2 = \rho C_{Dr} S_r^2 \]

Sensible Heat Flux:

\[ H_s \equiv \rho c_p \overline{wt} = \rho c_p C_{Hr} S_r (T_s - T_r) \]

Latent Heat Flux:

\[ H_L \equiv \rho L_v \overline{wq} = \rho L_v C_{Er} S_r (Q_s - Q_r) \]
Drag Coefficient

\[ C_{\text{Dr}} = \frac{k^2}{\left[ \ln\left(\frac{r}{z_0}\right) - \psi_m\left(\frac{r}{L}\right) \right]^2} \]

where \( k \) is the von Kármán constant, \( r \) is an arbitrary reference height, \( z_0 \) is the roughness length for momentum, \( L \) is the Obukhov length, and \( \psi_m \) is a stability correction.
## Compare Flux Algorithms

<table>
<thead>
<tr>
<th>Component</th>
<th>SHEBA</th>
<th>CICE</th>
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</thead>
<tbody>
<tr>
<td>$z_0$</td>
<td>Depends on $u_*$ and $C_i$</td>
<td>$5.0 \times 10^{-4}$ m</td>
</tr>
<tr>
<td>$z_T$, $z_Q$</td>
<td>Andreas (1987)</td>
<td>$5.0 \times 10^{-4}$ m</td>
</tr>
<tr>
<td>In low wind</td>
<td>Windless transfer, all fluxes</td>
<td>Windless transfer, only sensible heat, only stable</td>
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</tbody>
</table>
\[ z_0 = 0.135\left(\frac{v}{u_{*,B}}\right) + 2.30 \times 10^{-4}\tanh^3(13u_{*,B}) \]
$z_0 = 0.135\left(\frac{v}{u_{*,B}}\right) + 6.0 \times 10^{-4} \tanh^3(13u_{*,B})$
SHEBA Flux-PAM Site Atlanta
In the Arctic Ocean (Winter Only)
In the Weddell Sea (Winter)
Quantify Physical Roughness

A roughness parameter related to the surface variance (from Banke et al. 1980)

$$\xi^2 = \int_{\kappa_0}^{\infty} \Phi(\kappa) d\kappa$$

where $\kappa$ is the wavenumber, and $\Phi(\kappa)$ is the wavenumber spectrum of the surface elevation.

$\kappa_0$ is a cutoff wavenumber of 0.5 rad m$^{-1}$

(equivalent to a maximum wavelength of 12.6 m)
Summary

• Have presumed that a bulk flux algorithm tuned for multiple SHEBA sites would be good over any sea ice surface

• The SHEBA algorithm’s prediction for $z_0$ is too small, however, to simulate momentum transfer over the Weddell Sea

• Seem to need additional parameters to model a “local” value of $z_0$ over snow-covered sea ice