Including form drag in GCM code CICE: impact on model Arctic sea ice

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Vertically-integrated (i.e. horizontal) momentum balance is:

\[ m \frac{Du}{Dt} = \tau_a + \tau_w + \nabla \cdot \sigma - mf_C k \times u - mg \nabla H \]

mass \times acceleration = air + ocean + ice-ice + Coriolis “force” + gravity force from sea surface tilt
Vertically-integrated (i.e. horizontal) momentum balance is:

$$m \frac{Du}{Dt} = \tau_a + \tau_w + \nabla \cdot \sigma - mf_C k \times u - mg \nabla H$$

mass X acceleration = air drag + ocean drag + ice-ice force + Coriolis "force" + gravity force from sea surface tilt

Coon et al. (1974); Gray and Morland (1994)
Winter pack ice:

- Ridge and keel contribution
- High sea ice concentration -> Little floe edges
- No melt ponds
Different types of sea ice - Impact on form drag

Melt season:

- Ridge and keel contribution – reduced?
- Melt ponds could contribute to form drag
Different types of sea ice - Impact on form drag

Marginal Ice Zone:
- Ridge and keel contribution
- Floe edge contribution important
Different types of sea ice - Impact on form drag

Marginal Ice Zone:

- Ridge and keel contribution
- Floe edge contribution important

Important parameters of the model (in parenthesis notation of schematics):

- L : floe size (ls)
- A : ice concentration

Atmosphere:

- Hf : freeboard (hs)
- Hr : ridge height (hr)
- Dr : distance between ridges (dr)
- Df : distance between floes (ds)
- Lp : pond size (not shown)
- Hp : elevation of ice surface relative to pond surface (not shown)

Ocean:

- Hd : floe draft (D)
- Hk : ridge keel height (Hr)
- Dk : distance between keels (Dr)
Parameters in CICE
Parameters in CICE
Parameters in CICE

Ice concentration, A

Ice thickness, Hi (m)

Ridge height, Hr (m)
Parameters in CICE

Ice concentration, A

Ice thickness, Hl (m)

Ridge height, Hr (m)

Ridge frequency, 1/Dr (1/km)
Parameters in CICE
Parameters in CICE
Parameters in CICE
Parameters in CICE
Validation - Airborne data - IceBridge project

Collaboration UCL/NASA N. Kurz, S. Farrel, S. Laxon
Validation - Satellite data
MAPS of drag coefficients in CICE
Impact on Arctic sea ice thickness (m)
Impact on Arctic sea ice drift (cm/s)
A new parameterisation of the ice/ocean and ice/atmosphere momentum transfer is implemented in CICE and accounts for:
- Form drag from ridges/keels.
- Form drag from floe edges.
- Form drag from melt pond edges.
- Reduced skin drag due to a sheltering effect.

Calibration of the parameters of the models has started based on:
- Observations of the sea ice surface properties (roughness, ice concentration, floe characteristics...).
- Measurements of ice type and regionally specific neutral drag coefficients.

The impact of this new physics on the Arctic sea ice properties (thickness, concentration, drift) is large and could explain some of the differences between models and observations.