

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

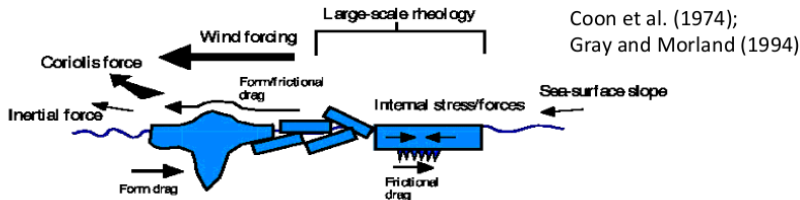
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16th AOMIP Workshop and 1st FAMOS meeting  
October 24, 2012

# Momentum balance - Danny's talk

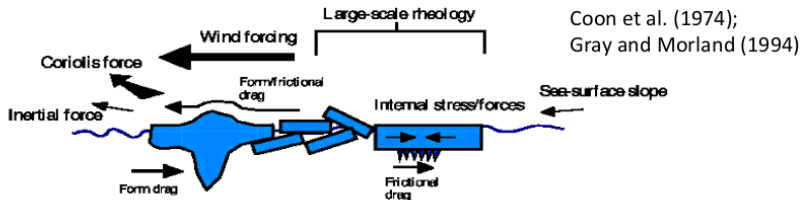


Vertically-integrated (i.e. horizontal) momentum balance is:

$$m \frac{D\mathbf{u}}{Dt} = \tau_a + \tau_w + \nabla \cdot \boldsymbol{\sigma} - m f_c \mathbf{k} \times \mathbf{u} - mg \nabla H$$

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

# Momentum balance - Michel's talk



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

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

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

# Different types of sea ice - Impact on form drag



Credit: LCDR John Woods

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



Credit: LCDR John Woods

Melt season :

- Ridge and keel contribution – reduced ?
- Melt ponds could contribute to form drag



Photo: S. Hendricks

# Different types of sea ice - Impact on form drag



Credit: LCDR John Woods

## Marginal Ice Zone :

- Ridge and keel contribution
- Floe edge contribution important



Photo: S. Hendricks



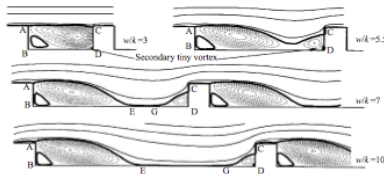
Photo: C. Lupkes

# Different types of sea ice - Impact on form drag



## Marginal Ice Zone :

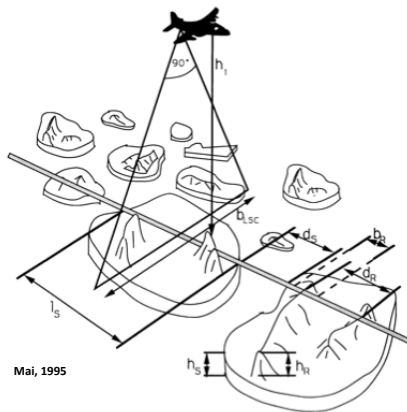
- Ridge and keel contribution
- Floe edge contribution important



Leonardi, J. Fluid. Mech. 2003



# Parameters of the model



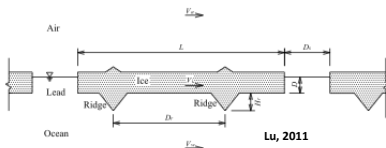
Mai, 1995

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

- $L$  : floe size ( $l_s$ )
- $A$  : ice concentration

Atmosphere :

- $H_f$  : freeboard ( $h_s$ )
- $H_r$  : ridge height ( $h_r$ )
- $D_r$  : distance between ridges ( $d_r$ )
- $D_f$  : distance between floes ( $d_s$ )
- $L_p$  : pond size (not shown)
- $H_p$  : elevation of ice surface relative to pond surface (not shown)

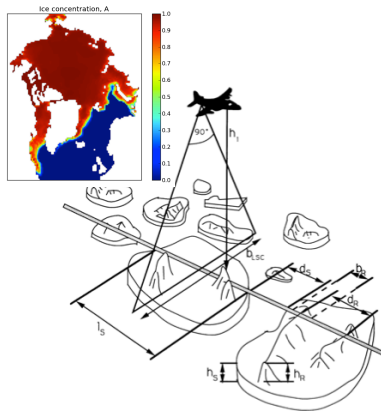


Lu, 2011

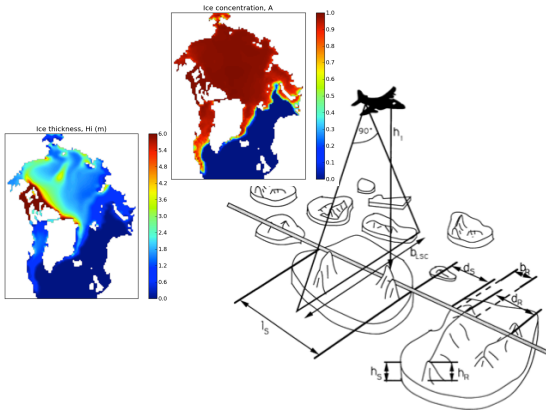
Ocean

- $H_d$  : floe draft ( $D$ )
- $H_k$  : ridge keel height ( $H_r$ )
- $D_k$  : distance between keels ( $D_r$ )

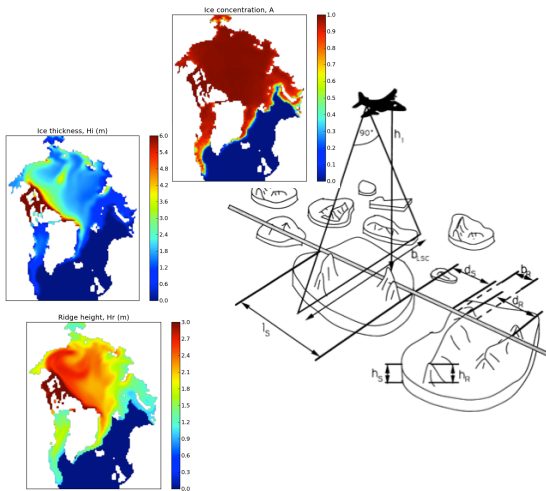
# Parameters in CICE



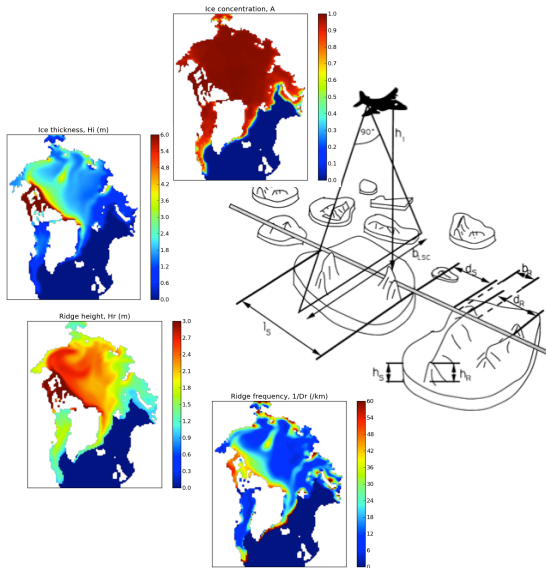
## Parameters in CICE



# Parameters in CICE

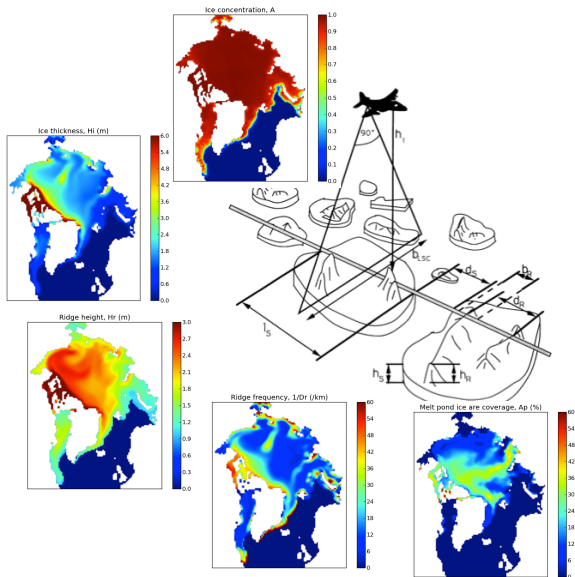


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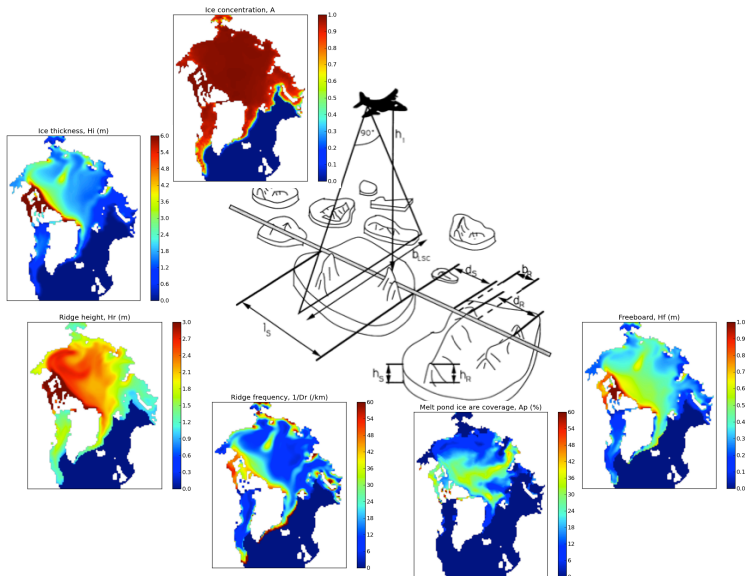




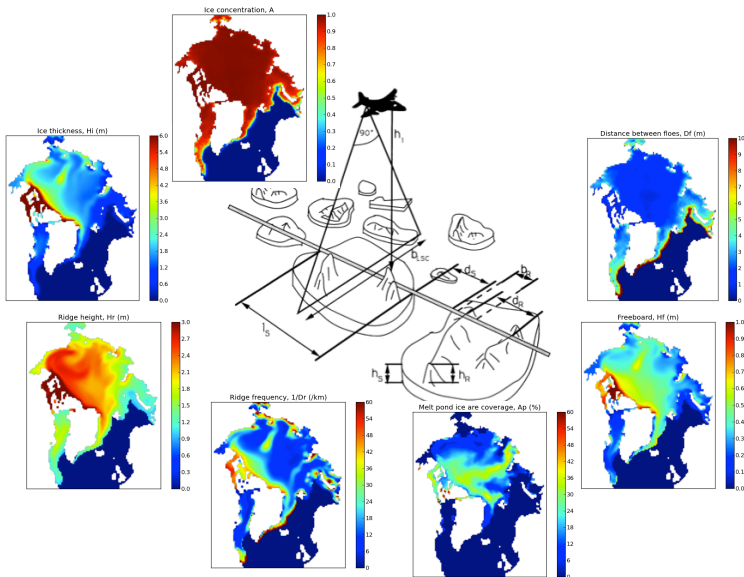
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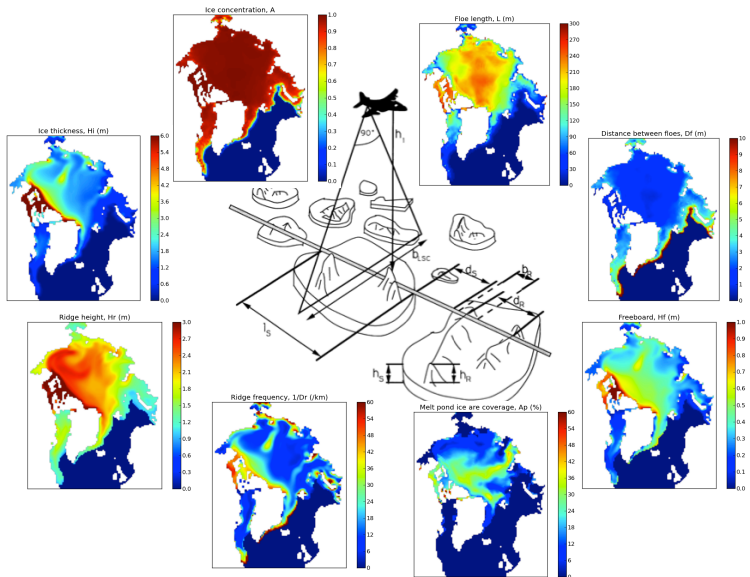
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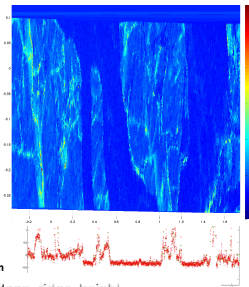
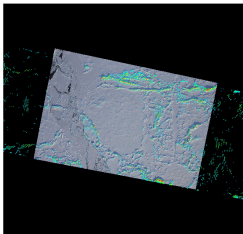
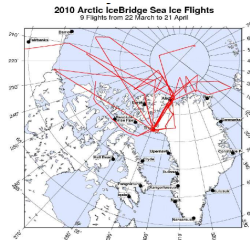
# Parameters in CICE



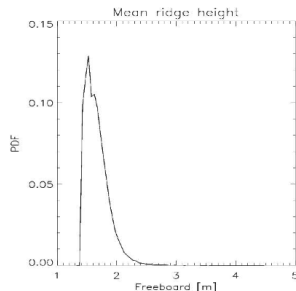
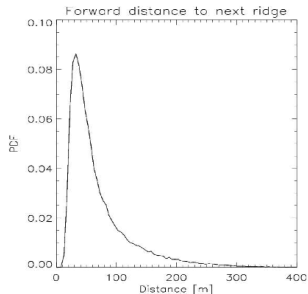
# Parameters in CICE



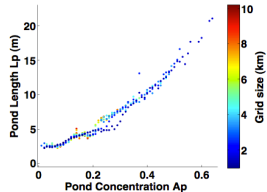
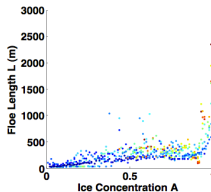
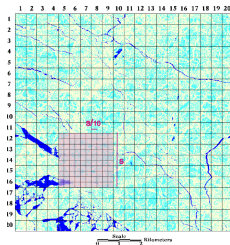
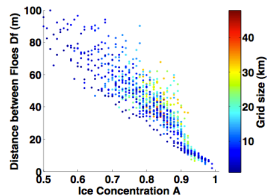
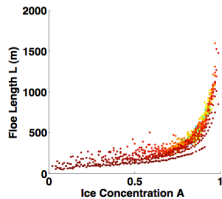
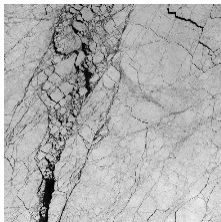
# Validation - Airborne data - IceBridge project



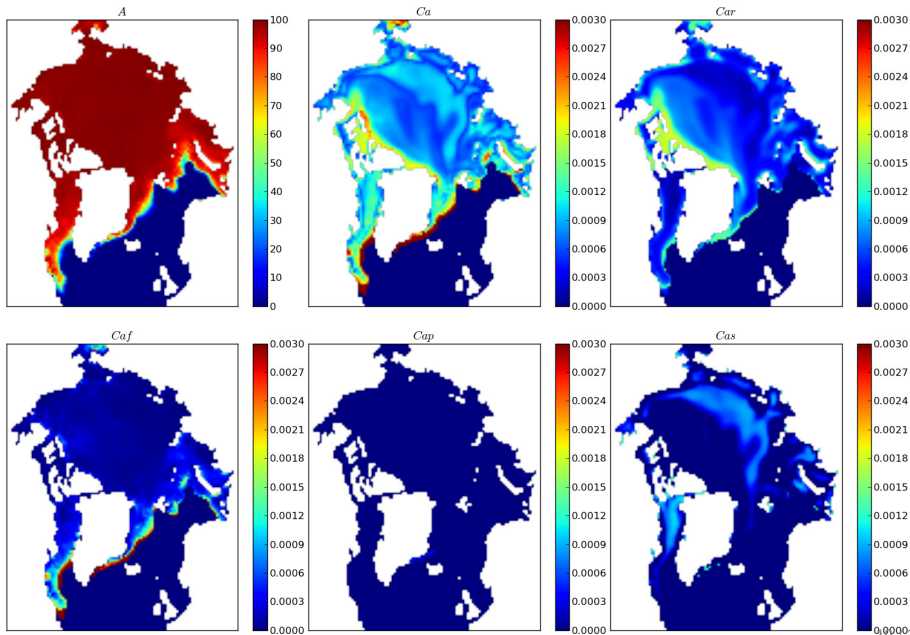
Collaboration UCL/NASA N. Kurz, S. Farrel, S. Laxon



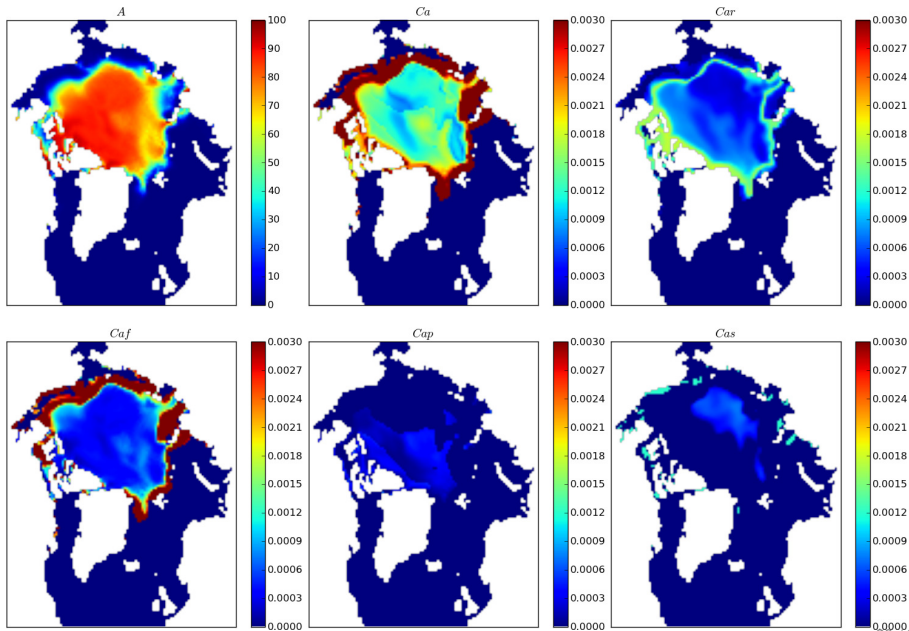
# Validation - Satellite data



# MAPS of drag coefficients in CICE

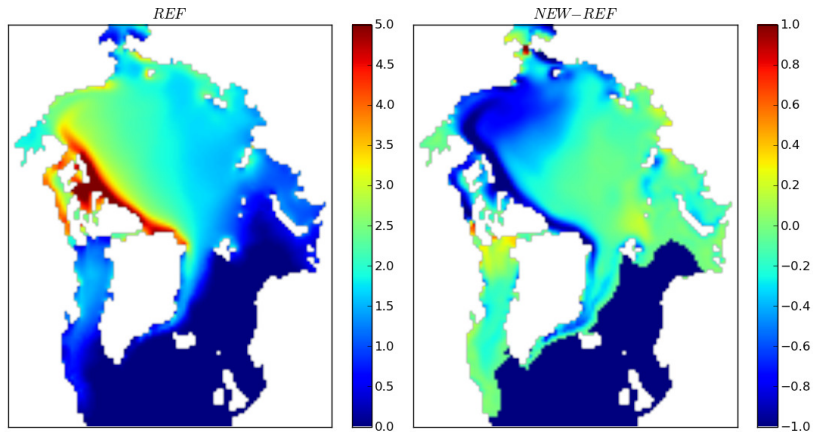


# MAPS of drag coefficients in CICE

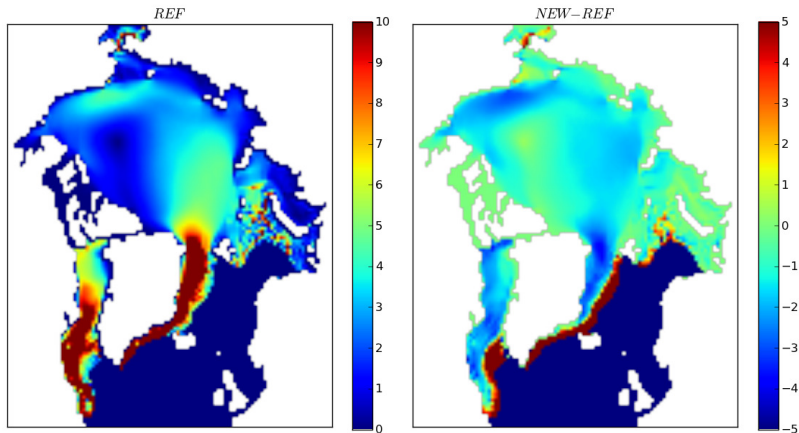




# Impact on Arctic sea ice thickness (m)



# Impact on Arctic sea ice drift (cm/s)



# Conclusion

- 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...).
  - on 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.