Improving sea ice model effective resolution through strength parameterisation

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Compressive strength of sea ice, P, must be parameterised in continuum sea ice models. The impact of two parameterisations was tested using the NEMO/SI^3 ocean/ice model.

Hibler (1979; H79) strength parameterisation:

$$P = \underset{\text{Ice strength parameter (constant)}}{P^*}\,\overset{\text{Ice thickness}}{h}\,\exp\left[-\underset{\text{Ice concentration parameter (constant)}}{C^*}(1-\overset{\text{Ice concentration}}{A})\right]$$

- Simple implementation
- Assumes thick and compact ice stronger than thin and low concentration ice, using grid-cell averages
- Does not consider physical assumptions around energy conservation

Rothrock (1975; R75) strength parameterisation:

- Based on amount of potential energy gained and frictional energy dissipated during ridging
- Utilises the sub-grid-scale thickness distribution
- Implemented here along with an exponential redistribution of ridged ice among thickness categories (Lipscomb et al., 2007)

$$P = \underbrace{C_{f_r} C_{p_e}}_{\text{Coefficients for frictional dissipation } (f_r) \text{ and potential energy } (p_e)} \int_0^\infty \overset{\text{Ice thickness}}{h}{}^2\, \underset{\text{Ridging mode}}{w}\,[\underbrace{g(h)}_{\text{Ice thickness distribution function}}]\,dh$$

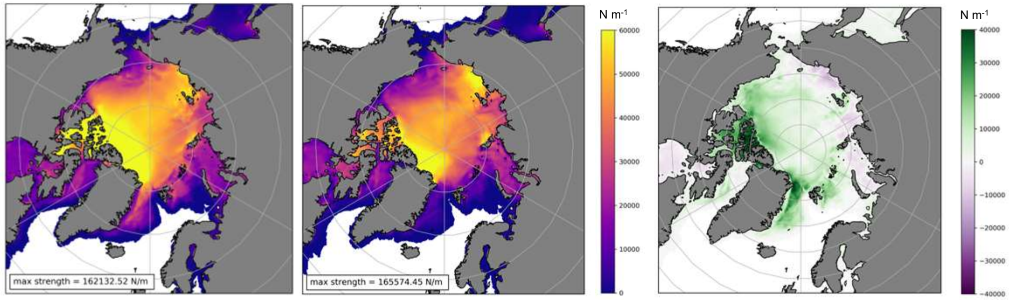
H79 is the standard strength formulation for the NEMO/SI^3 model. We recently added R75 to SI^3 within the EU IS-ENES3 project.

The impact of the two strength parameterisations was compared using the latest Met Office forced NEMO/SI^3 model configuration (based on NEMO release 4.2.2).

Resolution: eORCA025 (1/4 degree, tripolar grid)
Rheology: EVP (Elastic-Viscous-Plastic)
Forcing: CORE2 atmospheric forcing (Large and Yeager, 2009)

Results shown are for year 4 of model runs, which started in 1976.

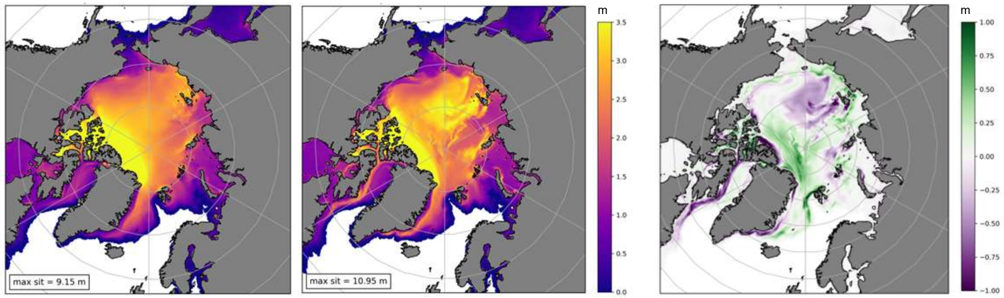
Figure 1: Impact on modelled sea ice compressive strength, and thickness



(a) Compressive ice strength: H79

(b) Compressive ice strength: R75

(c) Compressive ice strength difference: H79 minus R75



(d) Sea ice thickness: H79

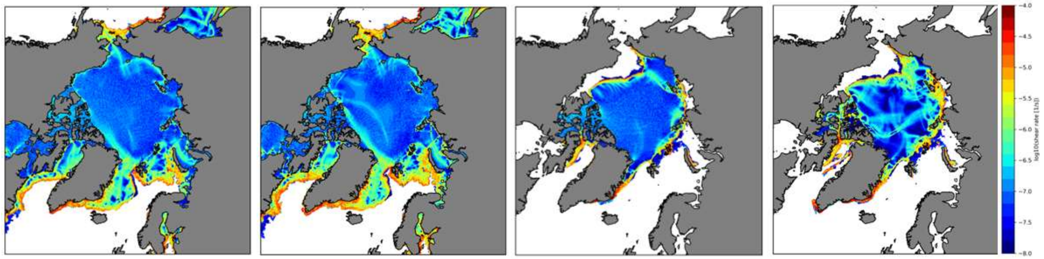
(e) Sea ice thickness: R75

(f) Sea ice thickness difference: H79 minus R75

▲ (a) – (c) : Monthly mean January 1979 Arctic sea ice compressive strength (P; N m^{-1}), for H79 and R75 strength parameterisations (a,b), and difference (c). In general, R75 strength is of a similar magnitude to H79, but there is substantial spatial and seasonal variation. June to August strength differences are very small, whereas R75 in September to November produces sea ice strength around half that of H79.

(d) – (f): Monthly mean January 1979 Arctic sea ice thickness (SIT; m), for H79 and R75 strength parameterisations (d,e), and difference (f). A substantial increase in the number and definition of features is seen for R75, compared to H79, persistent throughout all months.

Figure 2: Impact on modelled sea ice deformation



(a) Shear rate: H79, January

(b) Shear rate: R75, January

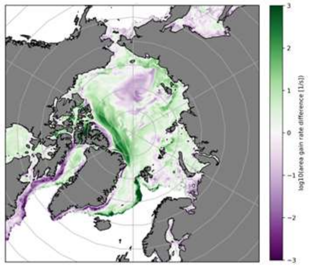
(c) Shear rate: H79, September

(d) Shear rate: R75, September

▲ Log$_{10}$ of the Arctic mid-month instantaneous maximum sea ice velocity shear rate (s^{-1}), for H79 and R75 strength parameterisations, January 1979 (a,b), and September 1979 (c,d). An increase in fracturing is seen for R75 compared to H79. In the ice growth season particularly (as shown here for September), a substantial increase in the number of fractures is produced. This is partly due to the increased spatial variability in R75 strength compared to H79, but also to the large reduction in overall strength for these months when using R75.

(e) Ridged ice gain rate diff, January ▶

Log$_{10}$ of monthly mean new ridged ice area gain rate difference (s^{-1}), for H79 minus R75, January 1979. Similar spatial patterns are apparent in the sea ice thickness difference (Fig. 1f). The R75 strength is influenced by the ridging, which is in turn influenced by the strength itself.



Summary

- The R75 sea ice strength formulation based on ridging is stable and works well in SI^3.
- R75 generates a greater number of features in the modelled sea ice compared to H79. Finer spatial detail can be seen in the sea ice thickness produced using R75, indicating an increase in model effective resolution.
- For most of the year, R75 sea ice strength is of a similar overall magnitude to H79, with some spatial variation. However, in the ice growth season of September to November, R75 strength is much reduced compared to H79. This contributes to a substantially greater number of fractures generated in the modelled sea ice for this season.

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