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Scaling properties of Arctic sea ice deformation in high-resolution viscous-plastic sea-ice models

Leads in viscous-plastic (VP) models

VP sea ice models at coarse resolution are known to reproduce statistical and scaling properties of sea ice deformation inappropriately [*Girard et al., 2009*], but …

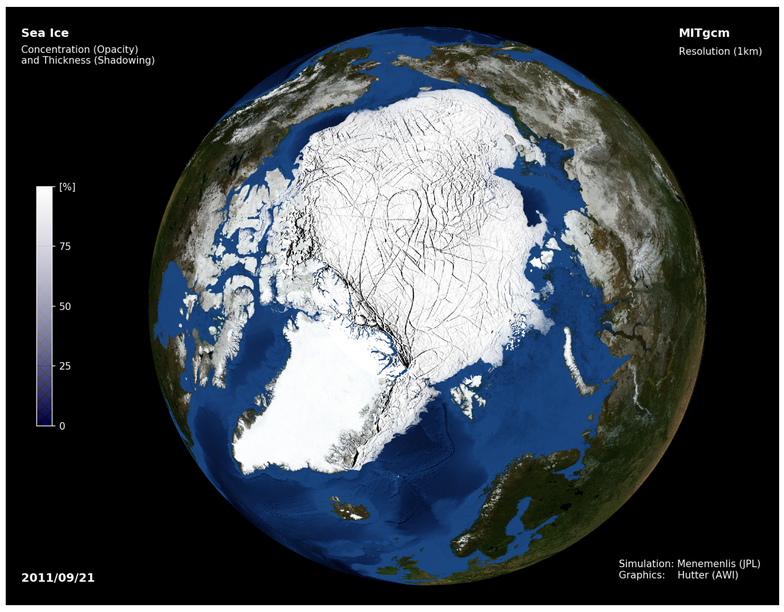


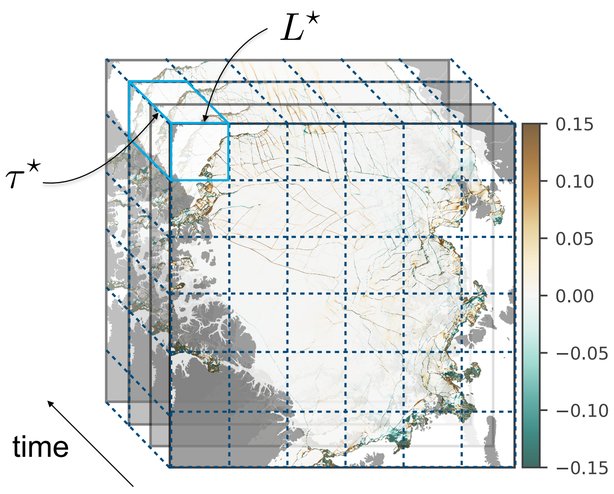
Figure: Sea ice in MITgcm model run with an average horizontal grid spacing of 1km in the Arctic. Sea ice deformation localises along linear failure lines collocated with low sea ice concentration and thickness

➡ At very high resolution leads emerge in viscous-plastic sea ice models.

Research Objectives: Do the emerging leads in VP sea ice models at very high resolution result in scaling properties of sea ice deformation comparable to satellite observations?

Scaling analysis

Adaption of the scaling analysis of *Marsan et al., 2004* for velocities on regular grids with integrated temporal scaling analysis.



Average strain rates over spatial and temporal scale $\left|\frac{\partial u_i}{\partial x_j}\right|_{L,\tau}$

↓

Compute deformation rates $\dot{\epsilon}_{L,\tau}$

↓

Power-law scaling $|\dot{\epsilon}_{L,\tau}| \sim L^{-\beta} \sim \tau^{-\alpha}$

Low scaling exponent ← similarity across scale ← propagation of stress

High scaling exponent ← heterogeneity across scale ← local deformation events

Evaluation with satellite data

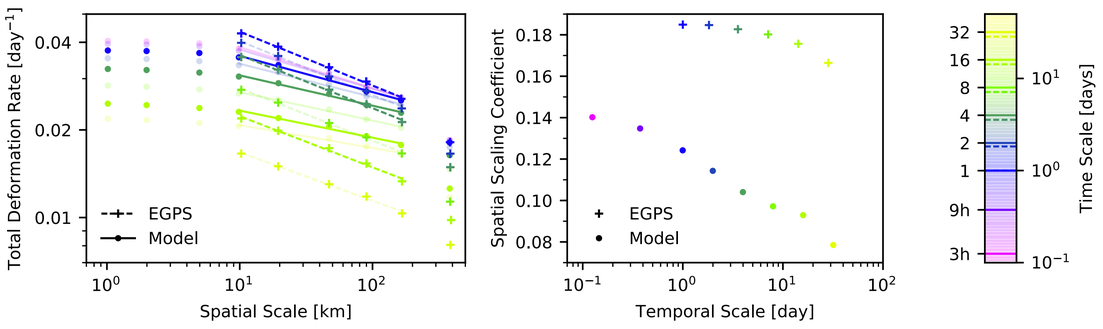
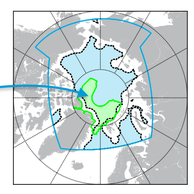


Figure: Spatial scaling properties of sea ice deformation in the model and for Envisat Geophysical Processor System (EGPS) drift data. The analysis is limited to EGPS region.

- **Agreement** of model results with observations regarding the **amplitude** of sea ice deformation and **space-time coupling**
- Different scaling exponents are influenced by
  - **small region** with high sea ice drift (*marked in green*)
  - **unfiltered EGPS data → overestimation**



Conclusions

- The resolved leads improve strongly the scaling properties of deformation rates in VP models.
- Arctic wide model analysis shows agreement with other RGPS studies and experiments with the EB-rheology.
- Seasonal and regional variation of spatial scaling is captured by the model.
- A more comprehensive model evaluation requires satellite data with larger spatial coverage along with higher temporal resolution and longer model simulation.
- VP rheology appears to be an appropriate framework for modelling sea ice deformation at high resolution

Modeled scaling properties

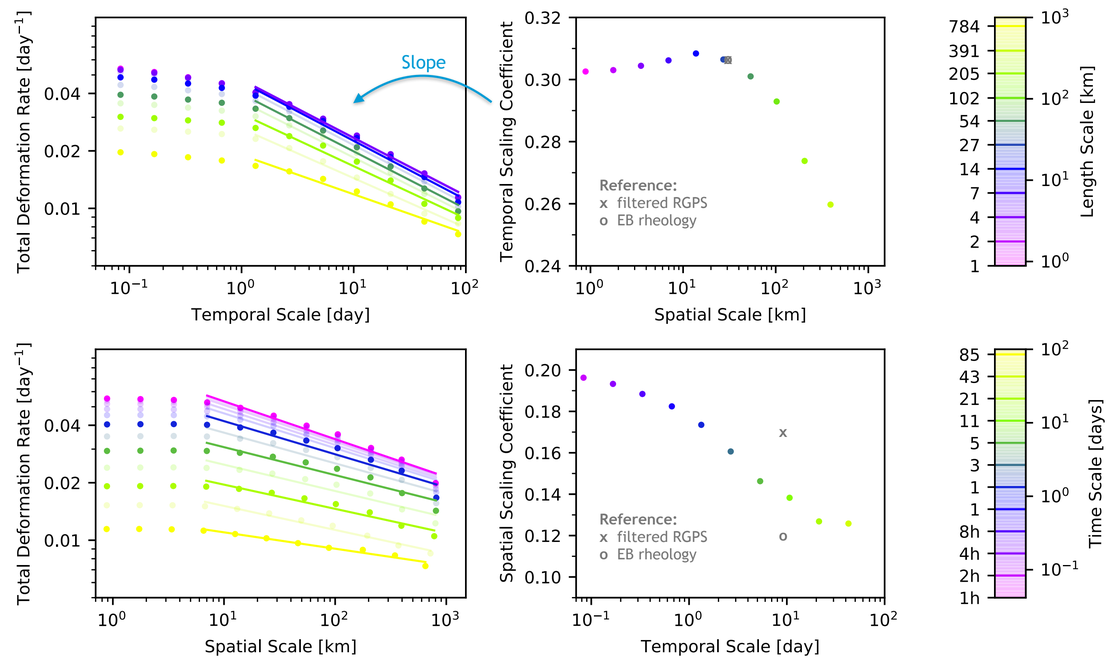


Figure: Temporal and spatial scaling properties of sea ice deformation (left column). Temporal and spatial scaling are coupled (right column). Reference data from *Rampal et al., 2016*

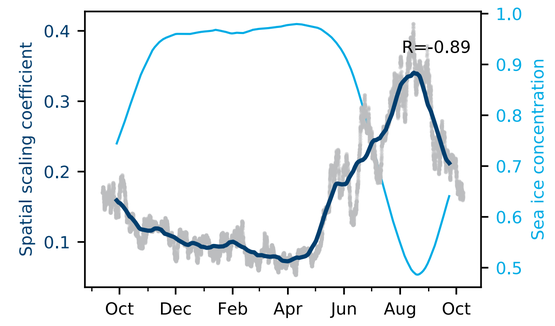


Figure: Seasonal variation of spatial scaling exponent and Arctic wide sea ice concentration

Seasonal variation

- In **winter** stronger stress propagation due to:
  - Higher ice strength: dense and thick ice (✓ modelled)
  - Confinement by coastlines (✓ modelled)
  - Stable atmospheric conditions (included in forcing)
- In **summer** local failure intensifies

Regional variation

- **Heterogenous** sea ice deformation in regions with
  - high sea ice drift (Fram Strait, Beaufort Sea)
  - open boundaries (Barents Sea)
- **Homogenous** sea ice deformation in regions with
  - high ice strength (Central Arctic)
  - confinement by coasts (Laptev Sea)

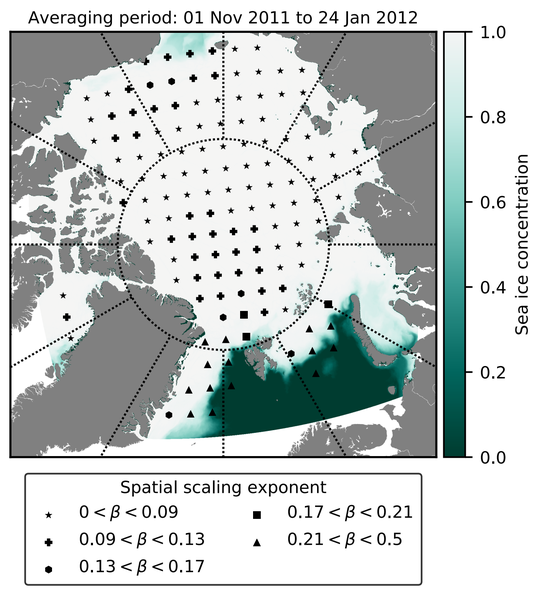


Figure (right): Regional variation of spatial scaling exponent and sea ice concentration

References
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Rampal, P., Bouillon, S., Ólason, E., & Morlighem, M. (2016). neXtSIM: a new Lagrangian sea ice model. The Cryosphere, 10, 1055–1073. http://doi.org/10.5194/tc-10-1055-2016

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