SPECIAL PROJECT PROGRESS REPORT

Reporting year	2015
Project Title:	Potential sea-ice predictability with a high resolution Arctic sea ice-ocean model
Computer Project Account:	spdelosc
Principal Investigator(s):	Dr. Martin Losch
Affiliation:	Alfred Wegener Institute
Name of ECMWF scientist(s) collaborating to the project (if applicable)	…………………………………………………
Start date of the project:	Jan 01, 2015
Expected end date:	Dec 31, 2017

Computer resources allocated/used for the current year and the previous one
(if applicable)
Please answer for all project resources

		Previous year		**Current year**	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	----------	----------	14,594,000.00	2,179,365.48
Data storage capacity	(Gbytes)	------------	----------	5,356.00	887.00

Summary of project objectives

Predicting sea ice conditions such as sea ice thickness and concentration will become increasingly important for Arctic marine operations, but the predictability of sea ice conditions on very short spatial scale and temporal scales is still unclear. Thus, we aim to establish rigorous comparison between observed fracture zones and leads in Arctic with structures that emerge in high-resolution (grid spacing of 5 km and smaller) numerical sea-ice simulations. We will develop new methods for meaningful comparisons of the ice deformation between the model simulations and retrievals from radar images. Finally, the predictability of the deformation features at these scales will be explored with high-resolution numerical simulations.

Summary of problems encountered

So far, we did not encounter any serious problems. The application (MITgcm, http://mitgcm.org) does not scale as well as expected, because of high global communication costs ("global sum").

Summary of results of the current year (from July of previous year to June of current year)

In the first phase of the project, we established a framework for cooperation of the modelling and observing system groups at the AWI. We have so far completed part of our first spinup simulations, computed the basic parameters indicating the sea ice deformations, extracted the most probable appropriate radar images from archives, and planned our approach to locate the appropriate region and time for the in-depth comparison.

We simulated the Arctic sea ice dynamics for eight years starting from the year 2002 until the year 2010. This configuration covers the entire Arctic Ocean and parts of the North Atlantic Ocean and the Bering Sea. This simulation with approximately 4.5 km horizontal resolution and with 1680*1536*50 = 129 Mio. computational cells and a time step of 240 sec is able to reproduce the quasi-linear structures emerged in high resolution simulations, e.g. Wang and Wang, 2009. The results of the performed numerical experiments will be used for preparing the boundary condition of the finer resolution configurations. They also provide a platform for developing new deformation comparison methods. Furthermore, we are using the numerical result for our primary visual comparison with radar images to find appropriate regions for more detailed investigations.

For the spinup-simulations, we deployed the MITgcm using the atmospheric fields of the ERA-Iterim The MITgcm is a portable open source code for sea ice-ocean (and atmosphere) simulations on massive parallel architectures with MPI and multi-threading (Hill et all. 2007). We used the Hibler (1979)'s viscous-plastic (VP) rheology to simulate the sea ice dynamics. The recently implemented efficient method of blank tile listing helped to reduce CPU requirements. This method drops the subdomains that are completely "dry" after domain decomposition. With this method, we were able to reduce the number of grid cells and CPU requirements by approximately 30%.

As the first step of developing the comparison methods, following the earlier works e.g. Kwok and Cunningham, 2012, we assumed that the quasilinear structures can be explained by divergence and shear of the sea ice as formulated by classical continuum mechanics. Since the time intervals of the radar image sampling is much larger than the time step of the numerical model, we explore potential sampling biases by comparing two methods of computing deformation parameters: (1) compute deformation (divergence, shear) from daily averages of the ice drift fields and (2) compute deformation every time step and form daily averages afterwards. As the divergence is a linear function of the drift field, the order of averaging is irrelevant for divergence, but there are differences in the obtained shear values. The final decision of selecting the most appropriate approach and analyzing the quantified difference will be made by comparing the results of the numerical model with the observations.

Secondly, we are interested in quantifying the role of the driving force e.g. atmospheric force, and the rheology of the sea ice on deformation of the sea ice especially for the shorter scales. We followed the work of Girard et al. 2009, and computed global mean of the total deformation from successively "coarse grained" model fields (See Figure 1 and Figure 2). We were able to reproduce the decreasing trend of the mean global deformation with increasing the spatial scale (e.g., Girard et al. 2009) but we plan to compare this method to Fourier spectral analyses. We expect that this method not only reduces the smoothing effects of the coarse graining algorithm, but also provides information about the transformation of energy between the scales.

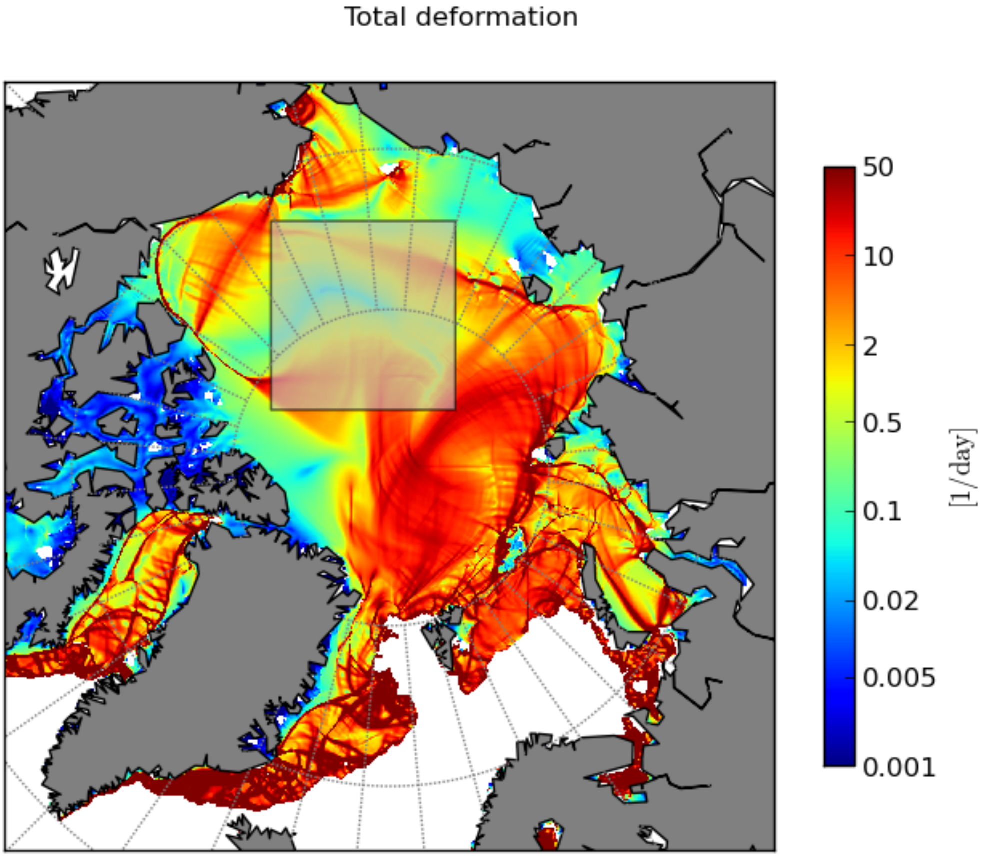

Figure 1: Example plot of the total deformation (per day, note the logarithmic color scale.) with a grid resolution of 4.5 km. The region shown by a box is selected randomly for the analyses.

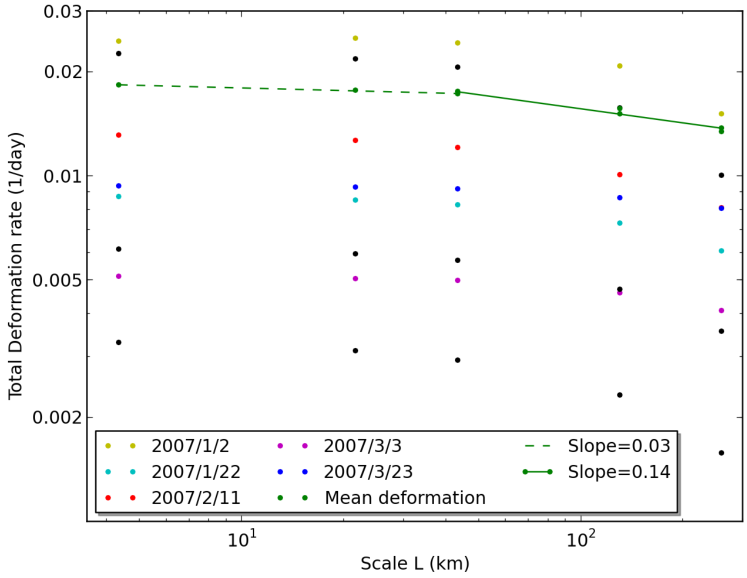

Figure 2: Total deformation rate as a function of spatial scale. The green line is the least-squares fit for mean total deformation rate between January and March of the year 2007.

References

Kwok, R., and Cunningham, G. F. (2012). Deformation of the arctic ocean ice cover after the 2007 record minimum in summer ice extent. *Cold Regions Science and Technology*, *76*, 17-23.

Girard, L., Weiss, J., Molines, J. M., Barnier, B., & Bouillon, S. (2009). Evaluation of high−resolution sea ice models on the basis of statistical and scaling properties of Arctic sea ice drift and deformation. *Journal of Geophysical Research: Oceans (1978–2012)*, *114*(C8).

Hibler III, W. D. (1979). A dynamic thermodynamic sea ice model. *Journal of Physical Oceanography*, *9*(4), 815-846.

Hill, C., Menemenlis, D., Ciotti, B., and Henze, C. (2007). Investigating solution convergence in a global ocean model using a 2048-processor cluster of distributed shared memory machines. *Scientific Programming*, *15*(2), 107-115.

Wang, K., and Wang, C. (2009). Modeling linear kinematic features in pack ice.*Journal of Geophysical Research: Oceans (1978–2012)*, *114*(C12).

List of publications/reports from the project with complete references

N/A

Summary of plans for the continuation of the project

We will perform a series of regional sea ice-oceanic simulations with finer horizontal grid size than the current configuration to verify the realism of the quasi-linear structures in shorter scales. We will configure these simulations using the outcome of the primary visual comparison of the available radar images and the previous numerical results. If the observation and modelling groups can not agree on an appropriate period of time for the quantified comparison, we will extend our primary investigation by continuing the simulations until the year 2012.

If the anticipated quantified comparisons using the intended diagnostic methods show good agreement between the simulations and the observations, the potential predictability of the coupled sea ice-ocean model will be estimated with the help of ensemble.