# ANOMALOUS DISPERSION OF SEA ICE IN THE FRAM STRAIT REGION

**Andrea Gabrielski*, Gualtiero Badin, Lars Kaleschke**
**Institute of Oceanography, University of Hamburg**
*** andrea.gabrielski@zmaw.de**

## Introduction

The Arctic experienced drastic changes in the recent years as sea ice is reacting very sensitively to climate change. A better understanding of sea ice dynamics is therefore crucial to understand how the climate system will evolve. The Fram Strait region is the main gateway for ice export from the Arctic into the North Atlantic and it is subject to a strong background flow due to strong winds and the East Greenland current (highest drift velocities in the whole Arctic). Lagrangian statistics are used to study the dispersion of sea ice in this important region by means of ice drift buoys.

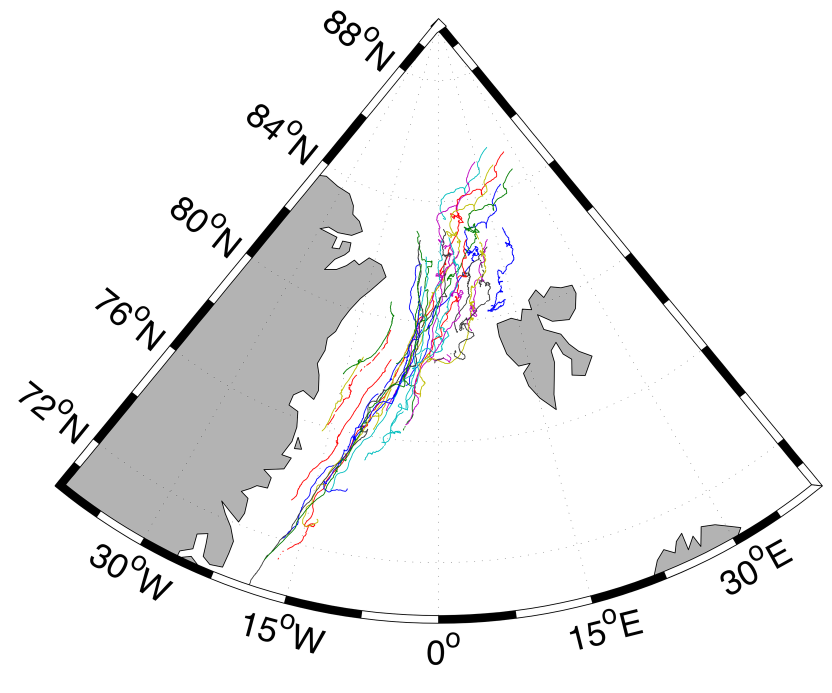


Figure 1: Map of the used ice buoys deployed near Fram Strait within the FRAMZY campaigns 2002, 2007, 2008 and 2009 as well as the ACSYS campaign 2003

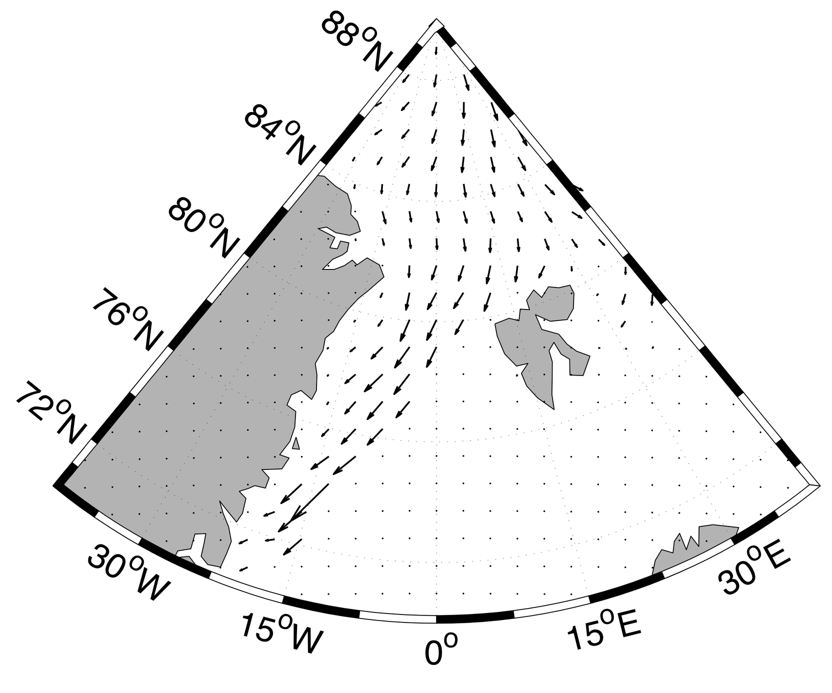


Figure 2: NSIDC ice drift velocities derived from satellite and buoy data exemplary as a 5 day average shown for every 4th grid cell (20. – 24.01.2008)

## Theory

Absolute disperison is a single particle statistic, defined as the mean square displacement, based on Taylor's work on diffusion by continuous movements [1]:

$$\left\langle r^2(t) \right\rangle = \frac{1}{N-1}\sum_{i=1}^{N}[(x_i(t)-x_i(0))^2 + (y_i(t)-y_i(0))^2].$$

Temporal scaling laws provide information about the underlying dynamics.

- For short times absolute dispersion scales with $t^2$ (ballistic regime).
- For long times a diffusive and an anomalous regime can be distinguished:
  - Absolute dispersion growing with $t^1$ describes a random walk.
  - Anomalous dispersion is found when $t^\alpha$, with $\alpha \neq 1$.

## Data & Methods

- A data set of 51 ice drift buoys deployed in the winter months of the years 2002, 2003 and 2007 - 2009 is used for the analysis (Fig. 1) [2-6].
- In order to eliminate the effect of the mean flow on the absolute dispersion we look at the cross-stream velocity component. The direction of the mean flow, averaged in every grid cell over different time intervals, is determined by means of the NSIDC ice drift product (Fig. 2) [7].
- Buoy data is averaged over two inertial periods (24 hours) to average out inertial oscillations.

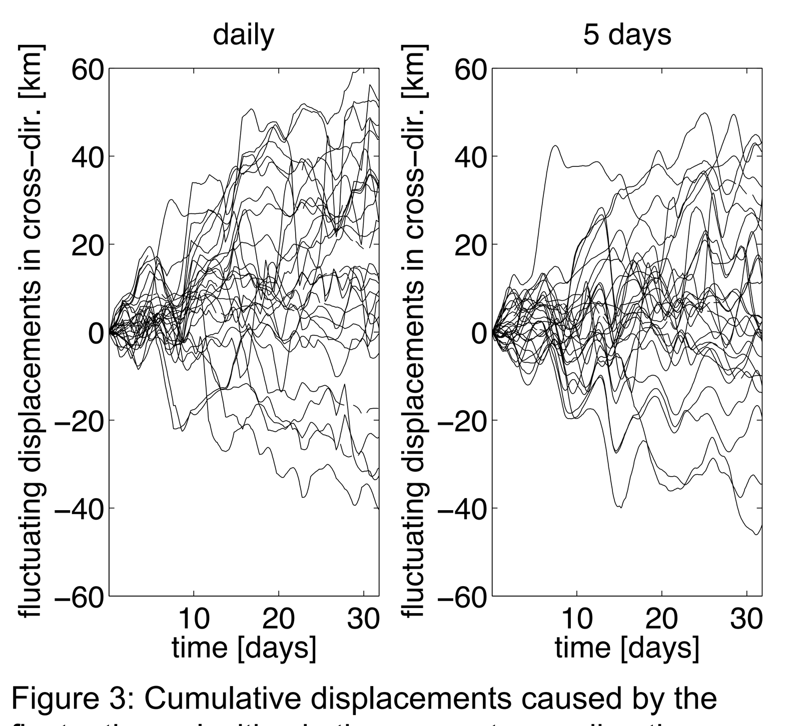


Figure 3: Cumulative displacements caused by the fluctuation velocities in the cross-stream direction

**References**

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## Results

- The cumulative displacements for the time intervals of 1, 3 and 5 days demonstrate the suitability of the 5 day average as the displacements become more symmetric about the y-axis (Fig. 3). The symmetry vanishes again for larger time intervals.
- The autocorrelation functions of the original data show the strong influence of the mean flow, which is removed when the cross-component is considered (Fig. 4).
- The zero-centered and symmetric distribution of the fluctuating displacements proves that the mean flow is correctly removed, only little differences exist for the different time intervals (Fig. 5).
- The PDFs are non-Gaussian, a random walk would yield a Gaussian distribution.
- The frequency spectrum has a slope slightly steeper than -2 (Fig. 6).
- The absolute dispersion is growing with $t^2$ when the mean flow is not removed (Fig. 7 inset). The curves of the absolute dispersion of the cross-stream component show that larger time intervals lead to a smoother curve with a slope close to 5/4 for time scales larger than 2 days (Fig. 7). For time intervals larger than 5 the slope of the absolute dispersion converges back to 2 (not shown). In 2D turbulence a slope of $\alpha$ = 5/4 corresponds to the relative dominance of deformation [8].

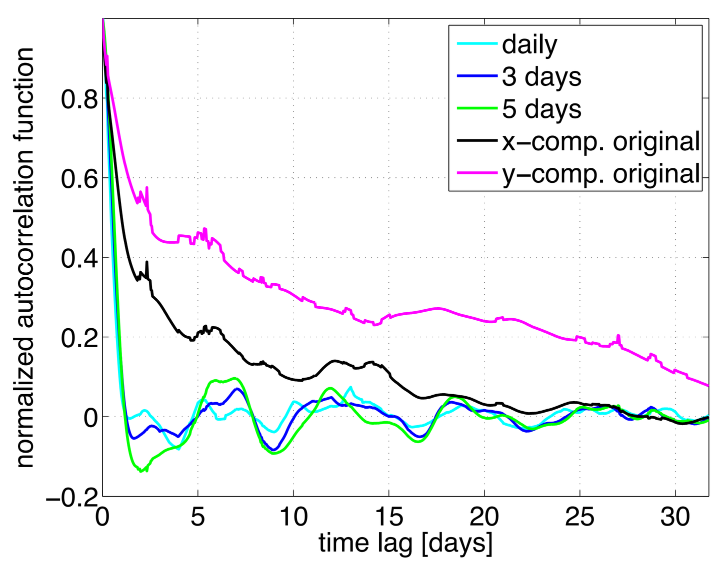


Figure 4: Normalized velocity autocorrelation functions of the original data and the fluctuation velocities for the different time intervals

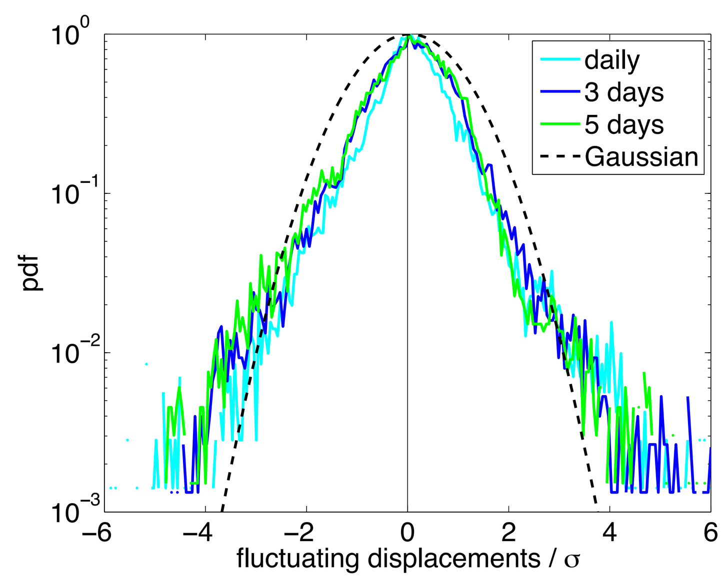


Figure 5: Probability density function of the displacements caused by the fluctuation velocities for the different time intervals with the Gaussian distribution for the 5-day average

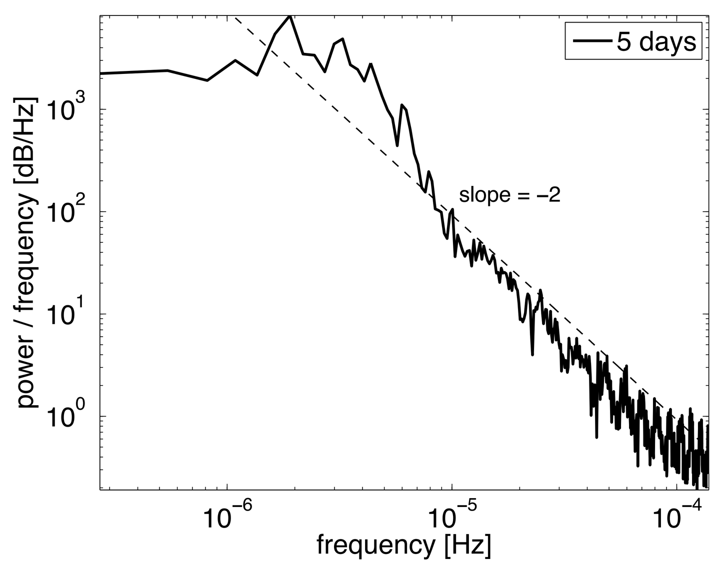


Figure 6: Frequency spectrum of the displacements caused by the fluctuation velocities for a time interval of 5 days

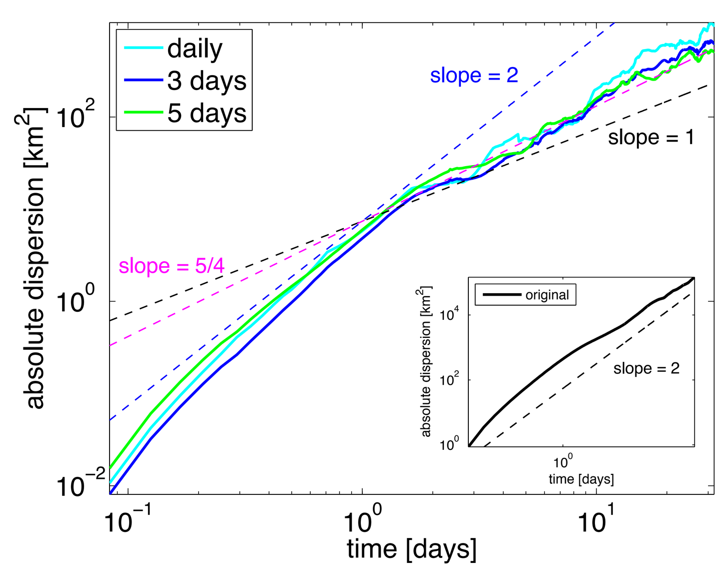


Figure 7: Absolute dispersion of the displacements caused by the fluctuation velocities for the different time intervals. Inset: Absolute dispersion of the original data

## Conclusion

- Sea ice motion in the Fram Strait region follows an anomalous dispersion growing with t^5/4. According to 2D turbulence this could be interpreted as a regime dominated by shear and divergence.
- The super-diffusive growth is in agreement with the non-Gaussian PDF and the spectrum with a slope close to -2 at frequencies shorter than the inertial frequency.
- Previous studies yield the same result for the absolute dispersion in the southern Beaufort Sea [9] and an absolute dispersion growing first with $t^2$ followed by a linear growth for time scales larger than 10 days in the central Arctic (Fram Strait region excluded) [10]. Differences may refer to the different underlying dynamics.

[8] Elhmaïdi, D., Provenzale, A. and Babiano, A. (1993), Elementary topology of two-dimensional turbulence from a Lagrangian viewpoint and single-particle dispersion, Journal of Fluid Mechanics, 257, 533–558.
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