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Fram Strait Sea Ice Volume Export Estimated Between 2003 and 2008 From Satellite Data

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Sea ice export through Fram Strait accounts for the largest portion of the total Arctic sea ice export and amounts yearly to about 10% of the total sea ice mass of the Arctic Ocean. Inter-annual perturbations in the sea ice transport through Fram Strait can modify the major water mass formation processes in the Greenland Sea and further downstream with consequences for the deep water formation and global ocean circulation. Satellite data from ICESat, AMSR-E and QuikSCAT are used to obtain the spatial distribution of the sea ice volume flux and a monthly ice volume export time series between 2003 and 2008.

Method

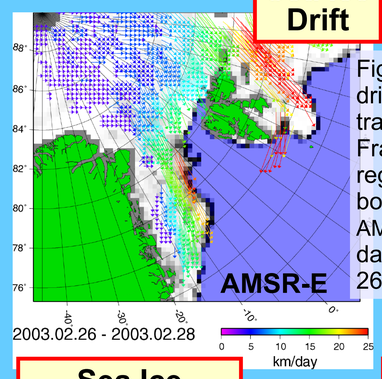

Fig. 1: Sea ice drift and concentration in the Fram Strait region obtained both from AMSR-E 89 GHz data on Feb. 26-28, 2003.

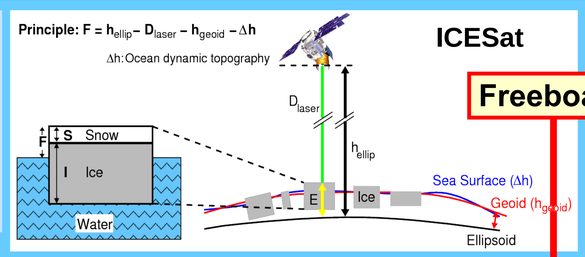

Fig. 2: Schemes of ICESat's measurement principle and a blow-up of an ice floe showing the quantities involved to obtain freeboard height *F*.

Estimates of sea ice thickness, concentration and drift from three satellite sensors are combined to derive the sea ice volume flux:

- **ICESat**/GLAS laser altimeter → ice freeboard height.
- **AMSR-E** → ice concentration and drift.
- **QuikSCAT** → multi-year ice fraction (ice density).

$$I = F\frac{\rho_W}{\rho_W-\rho_I} + S\frac{\rho_S-\rho_W}{\rho_W-\rho_I}$$

Results

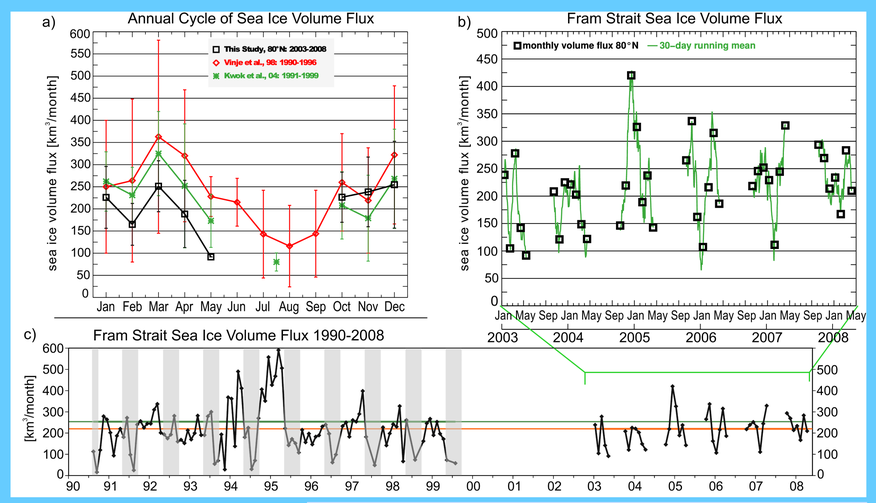

Fig. 3: (a) Seasonal cycle of Fram Strait sea ice volume flux. Black 2003–2008 (this study), red 1990–1996 (Vinje et al., 1998), green 1991–1999 (Kwok et al., 2004). (b) Time series 2003 to 2008 of winter sea ice volume export through Fram Strait at 80°N. (c) Extended Fram Strait sea ice export time series from 1990 till 2008. Green: 90-99 Oct.–Apr. mean; orange: 03-08 Oct.–Apr. mean. Grey bars denote summer months.

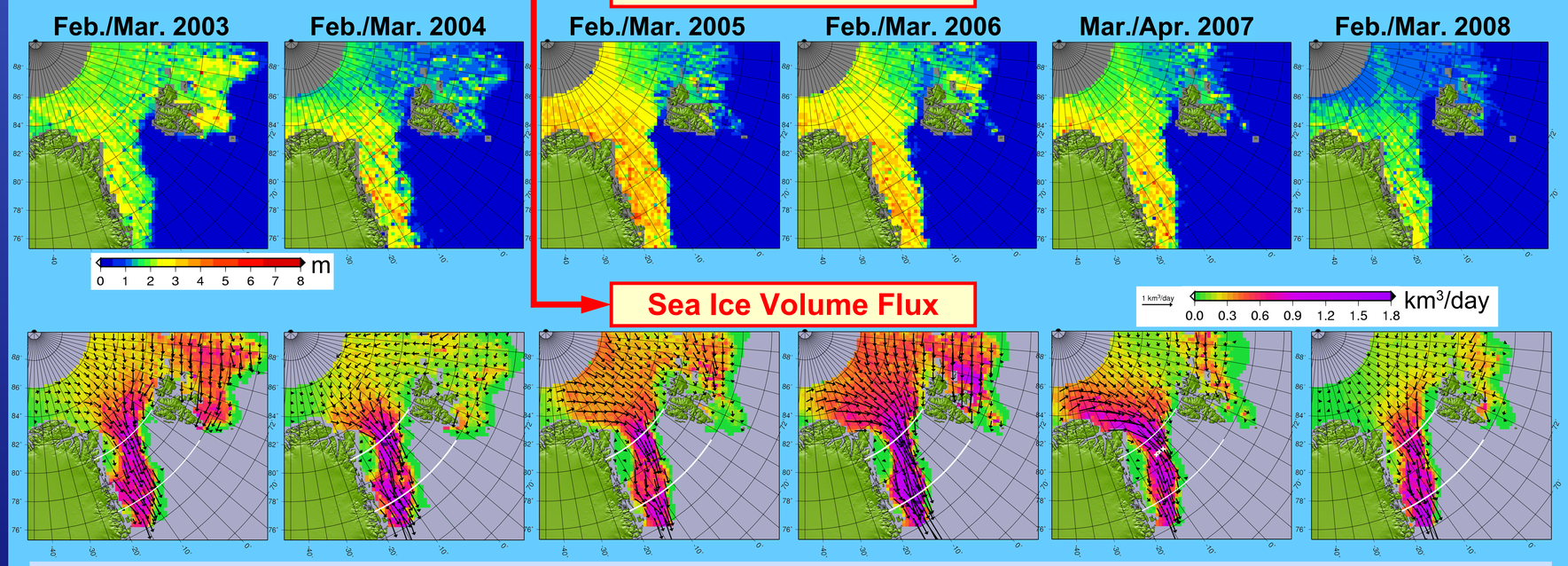

Fig. 4: Spatial distribution of sea ice thickness (upper row) and sea ice volume flux (bottom row) in the Fram Strait region for six out of eleven winter ICESat measurement periods between 2003 to 2006 (gray: no data or water; 25 km grid). The annual spatial variability is large. Two different ice volume flux source regions, from north of Greenland (e.g. Mar./Apr. 2007) and from the Transpolar Drift/Barents Sea (e.g. Feb./Mar. 2004), can be identified.

Validation

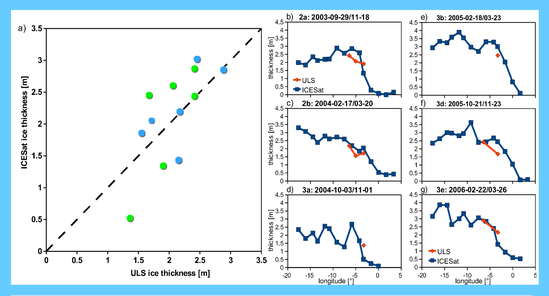

Fig. 5: (a) Scatter plot of sea ice thickness derived from ICESat versus ULS data for six ICESat periods (blue: winter; green: fall). (b–g) Zonal ice thickness transects at 79°N for the six periods (blue: ICESat; red: ULS).

Adapted ICESat ice thicknesses agree within 53 cm (bias -6 cm, correlation 0.71) with thicknesses derived from Upward Looking Sonars (ULS) at about 79°N in Fram Strait.

Conclusions: The distribution of the sea ice volume flux in the Fram Strait region shows high spatial and annual variability. The mean winter sea ice export between 2003 and 2008 amounts to 217 km³/month (max. 420 and min. 92 km³/month). Which is slightly smaller (-33 km³/month) than during the 1990s but lies within the natural variability and **no significant change of the total amount of Fram Strait sea ice export can be observed** since 1990.

References:

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- Kwok et al., 2004: "Fram Strait sea ice outflow", *J. Geophys. Res.*, 109 (C1) , C01009.
- Vinje et al., 1998: "Monitoring ice thickness in Fram Strait", *J. Geophys. Res.*, 103 (C5) , 10437-10449.

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