A changing dynamic in the Arctic sea ice system

Sea ice motion response to winds

Walter N. Meier and Julienne Stroeve

National Snow and Ice Data Center, University of Colorado at Boulder

http://nsidc.org

Introduction

Arctic sea ice is changing. It is thinning and extent is declining, particularly during summer. These changes are likely to have an impact on the sea ice dynamics on the system; e.g., a thinner, less consolidated ice pack will move more freely. To test this idea, ice motion data derived from enhanced resolution passive microwave imagery is used to evaluate how well the ice motion is simulated by a free-drift approximation

Sea ice data

Sea ice motion algorithm:

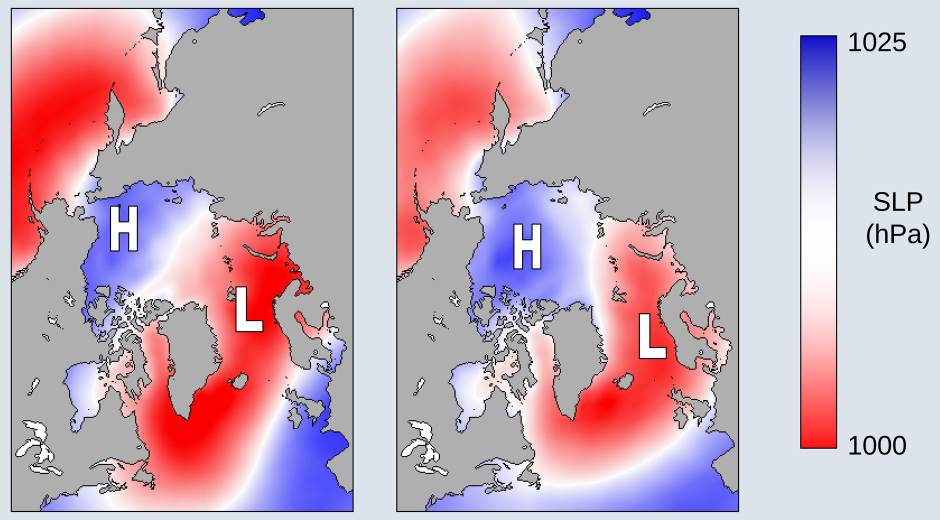
- Maximum cross-correlation (C. Fowler, Univ. Colorado)
- Feature tracking between two co-located images on same projection (here, polar stereographic) separated by time
- Optimal interpolation of motions from low frequency (36.5/37 GHz) and high frequency (89/85.5 GHz)

Spatial Resolution (km)	36/37 GHz		89/85 GHz	
	AMSR-E	SSM/I	AMSR	SSM/I
Footprint/IFOV	14 x 8	38 x 30	6 x 4	16 x 14
Standard Gridded	12.5	25.0	6.25	12.5
Enhanced Gridded	NA	8.9	NA	4.45
Final Gridded	12.5	12.5	6.25	6.25

Sea ice motion data:

- Need to have consistent spatial/temporal resolution for consistent motion tracking
- 1997: DMSP Special Sensor Microwave/Imager (SSM/I)
  - SIRF algorithm – reconstructs enhanced resolution sensor footprint (not simply spatial interpolation)
  - Developed by David Long, Brigham Young Univ.
- 2004: NASA EOS Advanced Microwave Scanning Radiometer (AMSR-E), standard resolution

Similar pressure field → similar wind forcing



Avg. Jan-Mar 1997 Avg. Jan-Mar 2008

From NCEP/NCAR Reanalysis, NOAA ESRL

Case studies, 1997 vs. 2008

January – March

Instead of comparing observed motions, compare agreement between observed passive microwave (**PM**) motion and free-drift model (**FD**) motion:

$$Ma_{ice} = \boldsymbol{F}_{wind} + \boldsymbol{F}_{current} + F_{tilt} + F_{Coriolis} + \boldsymbol{F}_{internal}$$

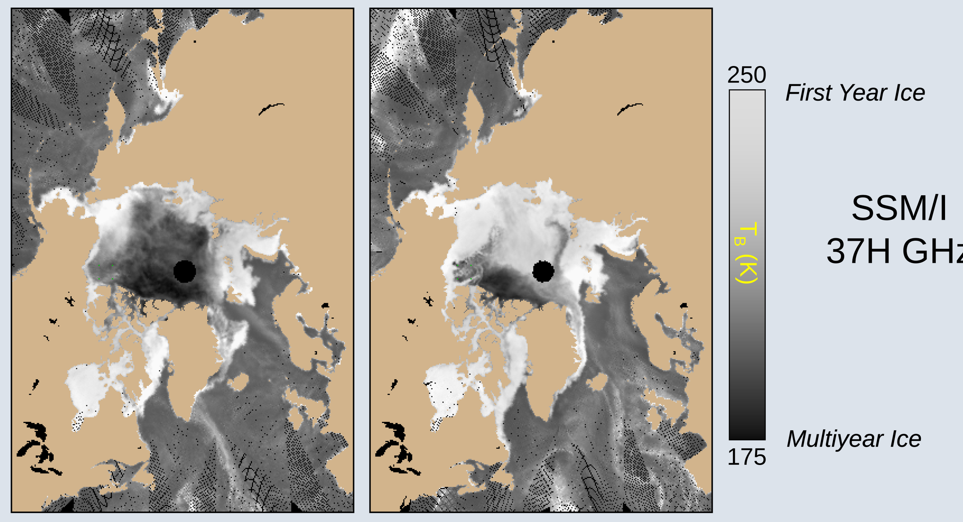
$V_{free\text{-}drift} \approx 0.02 V_{wind}$ *(30º to the right of wind)* (Nansen, 1902; Ekman, 1902)

$Ma_{free\text{-}drift} \sim dp/dx * f(\Phi)$ (Zubov, 1945)

Disagreement between PM and FD motions should be largely due to internal ice strength

1997: dominated by thicker multiyear ice

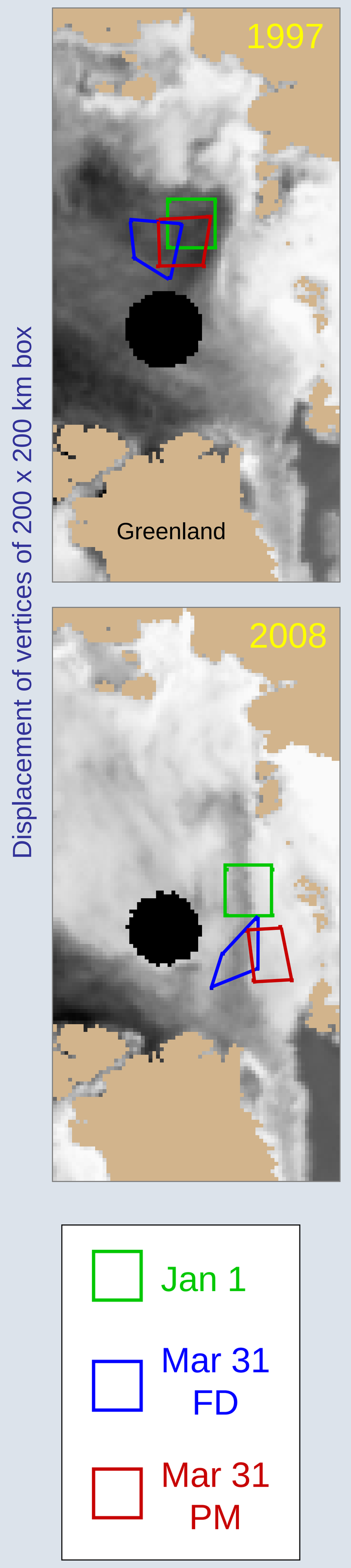
2008: significant first-year ice, multiyear ice more dispersed

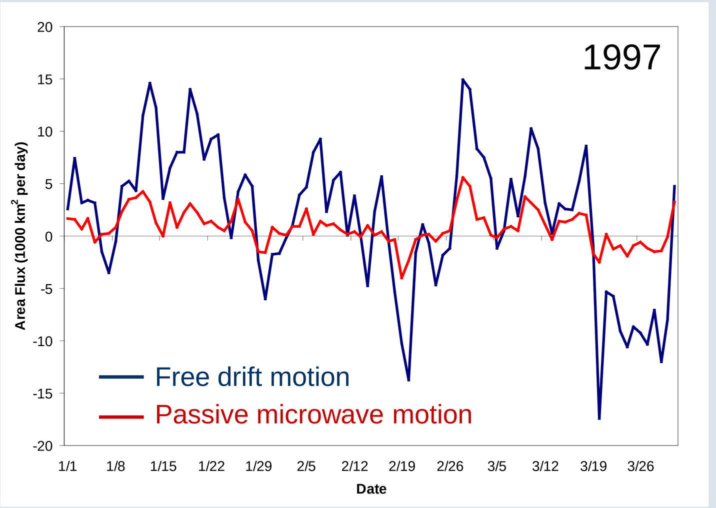


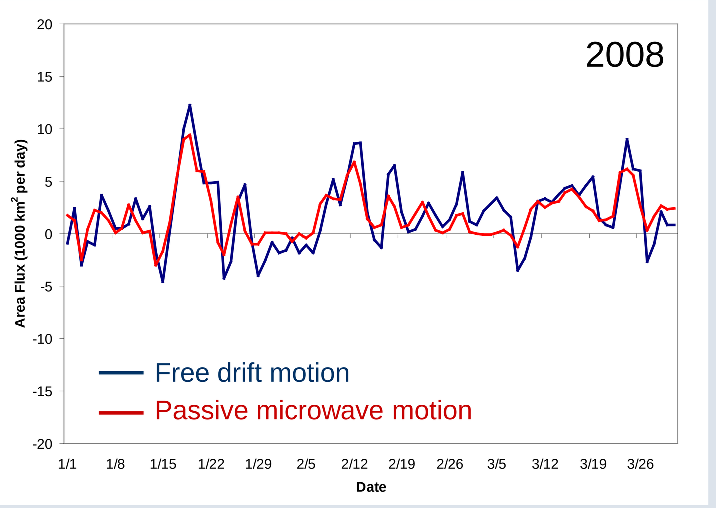
Jan 1997 Jan 2008

Case Study 1:

Multiyear ice vs. first-year ice







Area flux across top of box (200 km width)
positive values = flux toward bottom of image

1997:

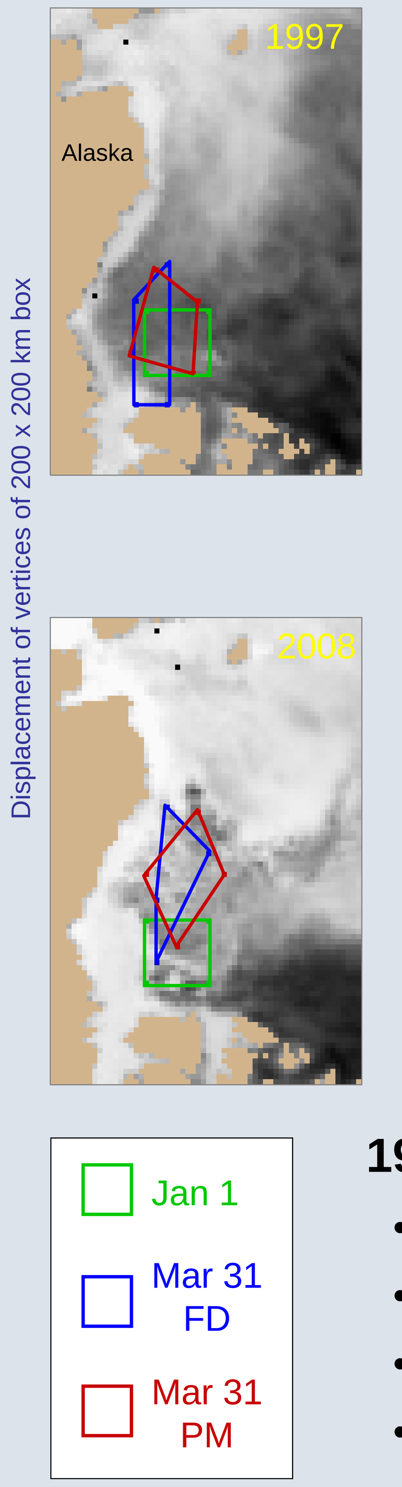
- Slower motion
- FD displacement ≈ PM displacement
- FD flux > PM flux
- FD variability > PM variability

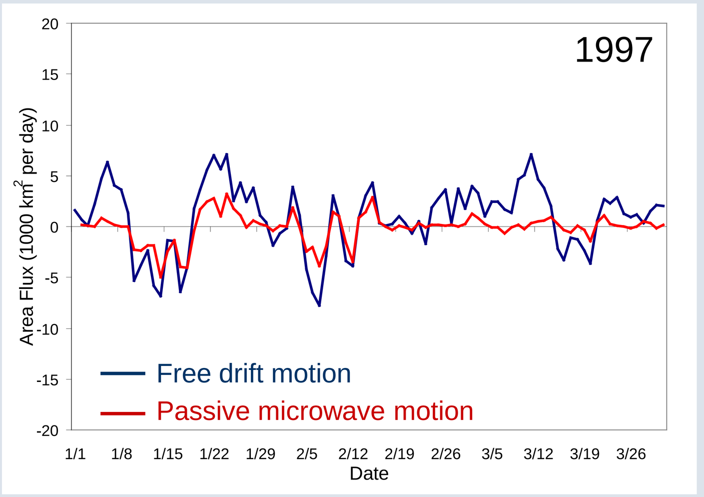
2008:

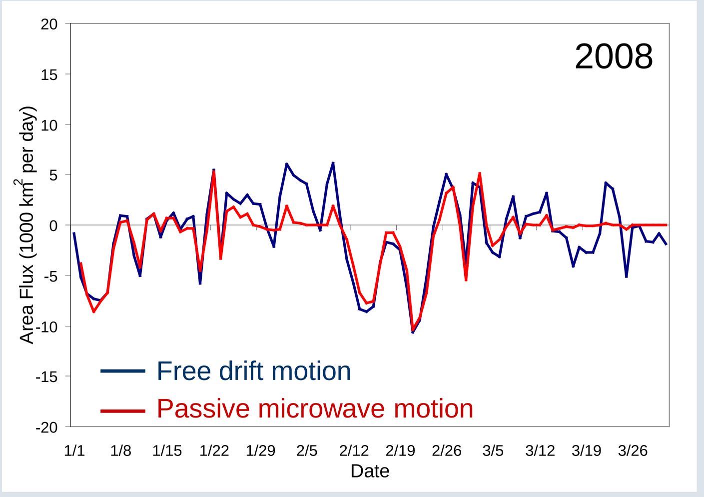
- Faster motion
- FD displacement ≈ PM displacement
- FD flux ≈ PM flux
- FD variability ≈ PM variability

Case Study 2:

Consolidated vs. unconsolidated multiyear ice







Area flux across top of box (200 km width)
positive values = flux toward bottom of image

1997:

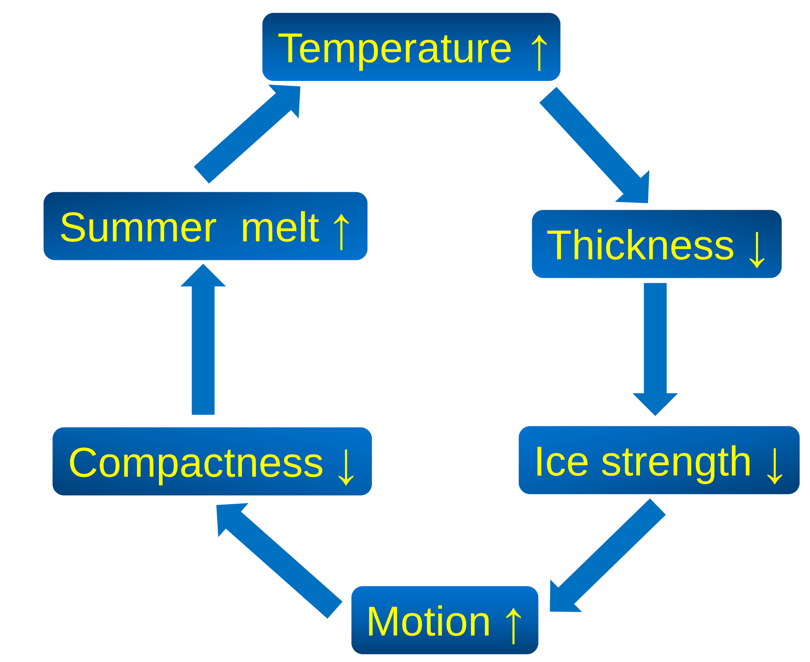
- Less variable motion
- FD displacement ≈ PM displacement
- FD flux > PM flux
- FD variability > PM variability

2008:

- More variable motion
- FD displacement ≈ PM displacement
- FD flux ≈ PM flux
- FD variability ≈ PM variability

A positive feedback from ice dynamics?

The PM motion compares more closely to the FD motion in 2008 than in 1997, suggesting that internal ice strength is decreasing due to the thinner and less consolidated ice pack. This indicates a potential positive feedback.



Such a feedback accelerates the loss of sea ice, complementing the effect of the sea ice-albedo feedback.

However, larger areas of open water, particularly in more northerly, colder regions may enhance fall ice growth, resulting in thicker first-year ice, more resistant to motion and to summer melt. This effect may mitigate the positive feedback effects.

Acknowledgments

Thanks to David Long, BYU for enhanced resolution SSM/I data, Dave Kindig and Matt Savoie for processing of NCEP SLP fields. This research funded by NASA grant NNG04GG72A.

Colorado University of Colorado at Boulder CIRES