

# Changes in Sea Ice Motion and Exchange in the Beaufort Sea: 1997-2012

M. Brady<sup>1</sup>, S. Howell<sup>2</sup> and C. Derksen<sup>2</sup> <sup>1</sup>University of Waterloo, Dept. of Geography <sup>2</sup>Environment Canada, Climate Research Division



## **The Beaufort Sea**

- West of the Canadian Archipelago and east of the Chukchi Sea.
- Complete ice coverage in winter growth season with retreat of sea ice edge in summer.
- Mix of seasonal and multi-year ice.







Environment Canada

## Ice Dynamics in the Beaufort Sea

- Circulates according to the anti-cyclonic Beaufort Gyre.
- Beaufort Sea a favourable location for dynamic and thermodynamic thickening.
- Surviving ice is recirculated out towards the Chukchi and East Siberian Seas.





Environment Canada

## **Recent Trends and Variability**

- Observed sea ice changes in the Beaufort Sea.
  - 1968-2012 mean September area trend:  $-5.4 \times 10^3 \text{ km}^2 \text{ year}^1$ .
  - Dramatic September decreases in recent years.
  - Some evidence of ice thinning.



Kowk and Rothrock 2009-GRL (right)

## aufort Sea. end: -5.4 x 10<sup>3</sup> km<sup>2</sup> year<sup>-1</sup>. ecent years.



Environment Canada

- How has sea ice velocity and ice area exchange changed in the **Beaufort Sea?** 
  - **Objective (i)** Estimate sea ice velocity in the Beaufort Sea using RADARSAT from 1997-2012 and compare the results with previous methods.
  - **Objective (ii)** Estimate the sea ice area flux (exchange) within and between the Beaufort Sea and surrounding regions from 1997-2012.
  - **Objective (iii)** Using the results from (i) and (ii), explore the drivers of recent variability in sea ice dynamics within the Beaufort Sea. Not going to address this objective in great detail.



Environment Environn Canada Canada

Environnement

## **Data: RADARSAT Image Acquisitions**

J	lan Fe	eb Ma	ar Aj	pr N	lay Ju	un .	ul A	Aug S	Бер	Oct	lov	Dec	Year Total
1997	114	81	104	90	119	125	189	177	52	14	171	120	1,356
1998	86	124	137	129	128	141	164	171	144	151	149	137	1,661
1999	132	125	144	147	173	185	189	188	172	187	176	185	2,003
2000	187	164	139	168	164	168	188	193	204	155	143	174	2,047
2001	162	166	184	176	194	183	246	239	211	224	218	208	2,411
2002	189	174	172	159	177	180	194	243	223	192	166	47	2,116
2003	215	171	199	165	182	218	256	257	259	256	234	230	2,642
2004	234	235	246	202	212	165	234	251	238	256	228	232	2,733
2005	234	186	198	176	186	157	182	221	217	200	233	242	2,432
2006	222	180	234	212	194	180	208	214	232	255	234	239	2,604
2007	292	246	293	292	282	278	297	294	295	273	214	188	3,244
2008	142	119	129	160	11	1	10	144	83	26	58	35	918
2009	23	20	25	26	43	34	75	99	102	75	34	32	588
2010	10	12	5	46	48	39	97	181	149	110	35	31	763
2011	27	19	20	46	45	32	81	155	170	160	73	45	873
2012	73	58	63	71	54	60	78	142	152	147	101	77	1,076
	Total Images											29,467	

## • Two time periods:

- January to December: 1997-2007
- July, August, September, October 1997-2012



Environment Canada

## **Ice Motion Tracking using CIS-ASITS**



Wohlleben et al. 2013-AO (top left)



Environment

## **Beaufort Sea Ice Area Exchange**

- Similar ice flux estimation technique as Kwok (2006)-GRL and Howell et al. (2013)-JGR
  - Identify gates, estimate ice transport and produce net monthly exchange; uncertainty is dependent on length of gate





Environment Canada

- Sea Ice Velocity
  - Monthly maps from 1997-2012 at 25 km and working on 5 km
  - Continuous time series for JASO from 1997-2012
  - -16-year mean was 4.78 km day<sup>-1</sup> (±3.30 km day<sup>-1</sup>)
  - October showed highest monthly drift with mean of 6.5 km day <sup>-1</sup>





Environment Canada

- Confident (mostly) in 1997-2007 estimates and can make them available.
- Positive trend in 1997-2012 JASO sea ice drift (not shown)
  - Since 2008, CIS-ASITS picking up more problematic vectors perhaps because of more extreme melt.





Environment Canada

# **Results: Objective (i)**

- Comparison with independent datasets
  - CIS-ASITS showed consistent positive mean bias ranging from 0.63 to 2.02 km/day – more work to be done here.



Environment Canada

# Results: Objective (ii) JASO Ice Flux

- Clear declines in MYI concentration at Prince Patrick and Southeast Beaufort
- Barrow gate shows variability <sup>b.</sup> in flux and MYI concentration, <sup>(III)</sup> with dramatic decreases in flux after 2007







Environment Canada

## **Results: Objective (ii) JASO Net Ice Flux**

Further emphasises the changes at the Barrow gate (bottom-left)





Environment Canada

# Results: Objective (iii) JASO Net Flux

## September median sea ice concentration



Kwok and Cunningham 2010-GRL (right)









## More melt in the Beaufort Sea during the summer

\*

Environment Canada

## Conclusions

- Positive trend in sea ice drift in the Beaufort Sea - Requires more investigation
- CIS-ASITS compares best with RIPS likely because of high spatial resolution
  - Investigate positive bias in more detail.
- Less ice area export via the Barrow gate 2008-2012
  - Sea ice melts before it can recirculate, overturning the conventional notion of the Beaufort Sea being a haven for ice to grow to a region where ice is lost (i.e. cemetery)



Environment Environn Canada Canada

Environnement

- Update time series to include 2013 and 2014
- Further explore the positive bias in CIS-ASITS velocity estimates compared to other datasets
- Validate positive trend in JASO sea ice drift from 1997-2012 (not shown)
- Use winter month sea ice velocity estimates from 1997-2007 and look at the correlation between sea level pressure gradients at the exchange gates during the winter months to establish poxys to validate summer flux estimates.



Environnement

# Thank You

