



→ MWBS | MAPPING WATER BODIES FROM SPACE 2015 CONFERENCE

EVIDENCE OF RECENT CHANGES IN THE ICE REGIME OF HIGH ARCTIC LAKES FROM SPACEBORNE SATELLITE OBSERVATIONS

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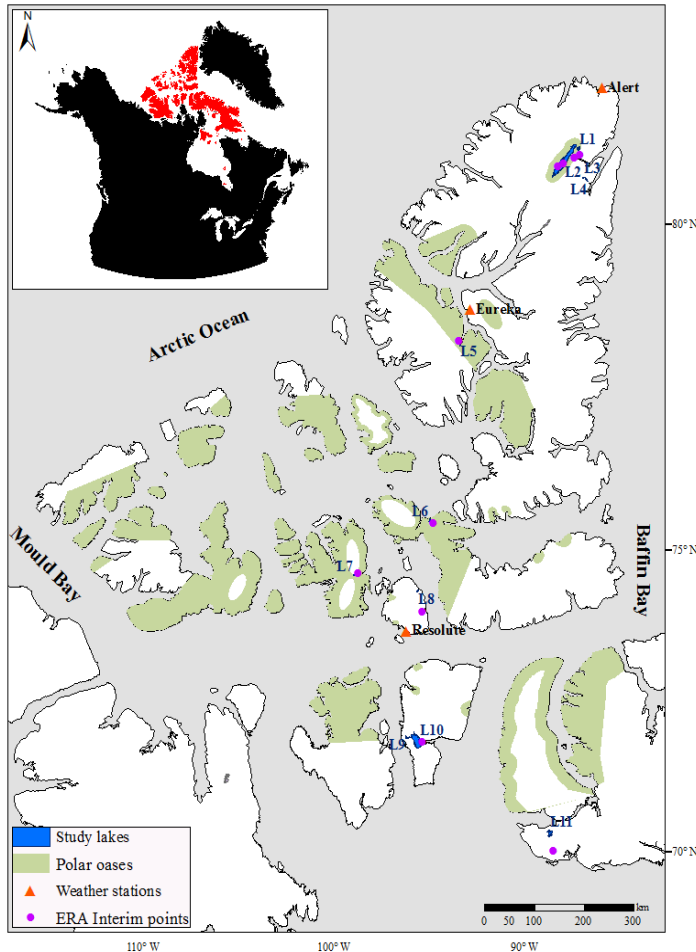
18–19 March 2015 | ESA-ESRIN | Frascati (Rome), Italy

- ❑ To document and analyze the response of High Arctic lakes to recent climate conditions:
 - start and duration of ice break-up
 - timing of summer minimum ice cover
 - presence/persistence of perennial ice
 - response of lakes in polar desert vs. those in polar oasis environments

- ❑ Changes in the ice cover of high-latitude lakes:
 - are good indicators of changes in climate
 - control changes in lake water temperature
 - promote additional light availability
 - lead to longer growing seasons (e.g. a diversified planktonic flora, an overall increased rate of primary production) as a result of shorter ice seasons
 - lead to changes in the chemical properties of lakes
 - impact habitat availability for certain species of fish and birds



Study Area



- ❑ 11 lakes in the Canadian Arctic Archipelago (CAA), including Lake Hazen, world's largest lake north of the Arctic Circle
- ❑ Lakes are ice covered for more than 9 months/year
- ❑ Some maintain a perennial ice cover
- ❑ **Polar deserts (pd)** – cold, dry climate (7 lakes)
- ❑ **Polar oases (po)** – warmer climate, more vegetation and higher biological diversity (4 lakes)

❑ C-band SAR acquisitions (1997-2011):

- RADARSAT-1/2 (ScanSAR Wide Swath B) (100 m, with a pixel spacing of 50 m – 2x2 block averaged to 100 m)
- ASAR (Wide Swath) (150 m spatial resolution, with a pixel spacing of 75 m)

❑ Optical imagery (1997-2011):

- Landsat 4/7 (30 m spatial resolution)

❑ Climate data (1997-2011):

- Weather station records (Alert, Eureka, Resolute, NU)
- ERA-Interim Reanalysis data ($\sim 0.75^\circ \times 0.75^\circ$ resolution)

Year of observations	RADARSAT-1	RADARSAT-2	ASAR
1997	231	-	-
1998	761	-	-
1999	787	-	-
2000	718	-	-
2001	1777	-	-
2002	1476	-	-
2003	1431	-	-
2004	1392	-	-
2005	1282	-	126
2006	1202	-	403
2007	1435	-	316
2008	1100	2740	339
2009	65	1561	539
2010	155	1077	380
2011	-	-	855
Total	13,812	5,378	2,958

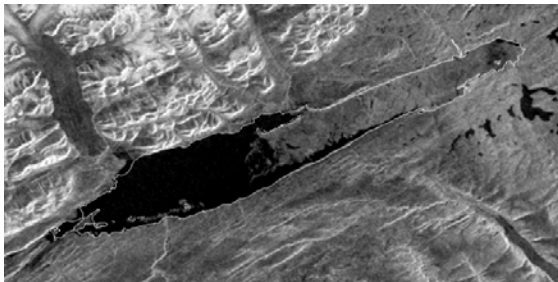


> 2000 Landsat images

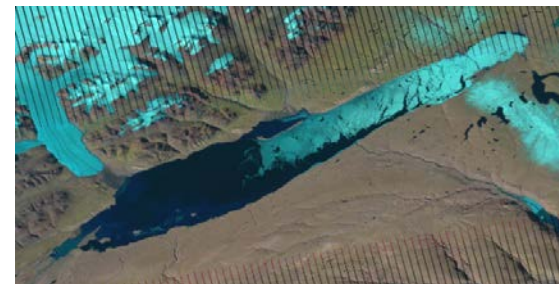
Number of images used for analysis

- ❑ SAR image segmentation: the unsupervised K-means algorithm
- ❑ ~1600 SAR segmented images in order to derive ice/open water fractions

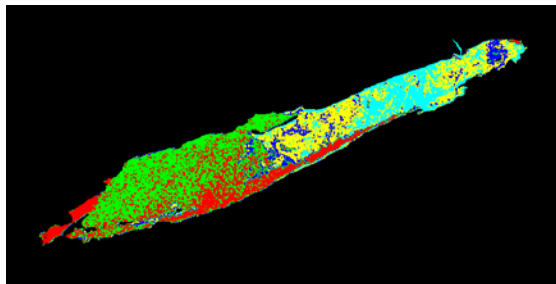
ASAR, 19 July 2010



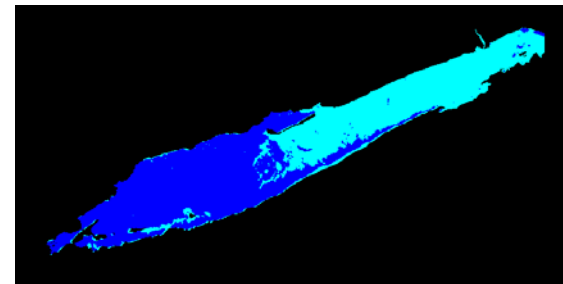
Landsat, 19 July 2010



K-means classified image (5 clusters)



Two-class map of ice and open water



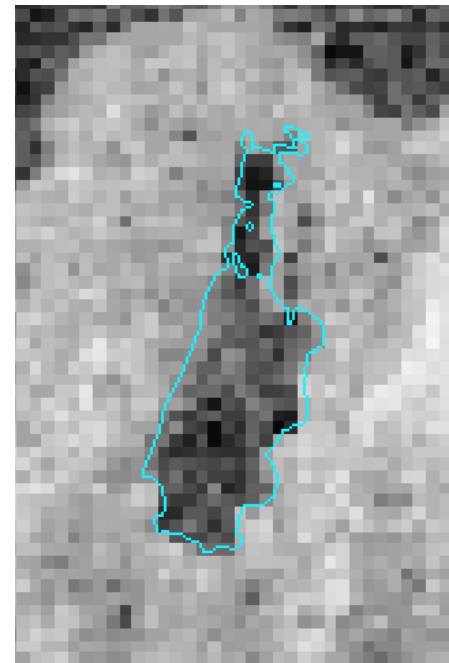
Histogram statistics (text files) – ice and open water fraction (%)

- ❑ Spatial resolution of RADARSAT-1/2 ScanSAR Wide Swath and ASAR Wide Swath = too coarse to detect melt onset on small lakes (1-5 km² surface area)

Landsat, 10 July 2003



RADARSAT-1, 11 July 2003



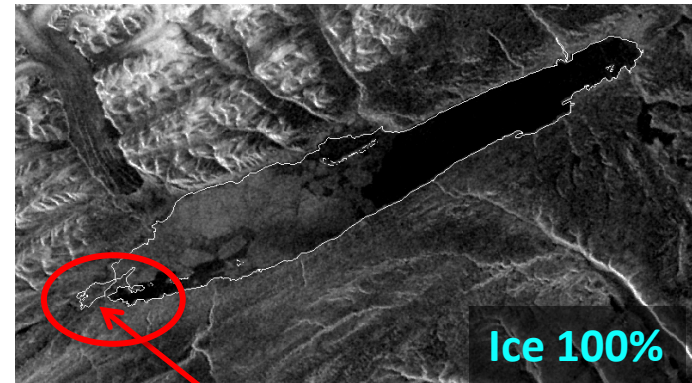
The Ice Season

Landsat, 8 June 2010



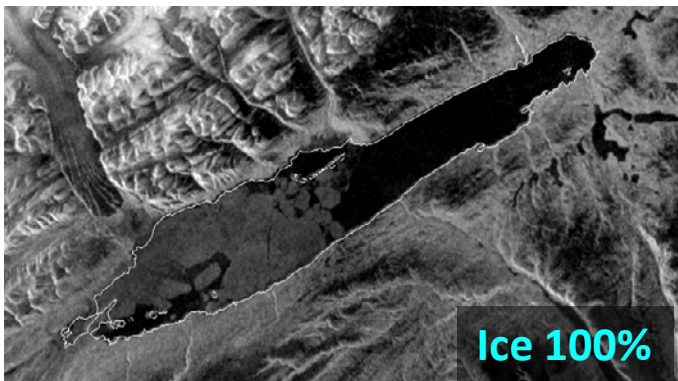
melt onset observed

ASAR, 9 June 2010



melt onset not detected

ASAR, 12 June 2010

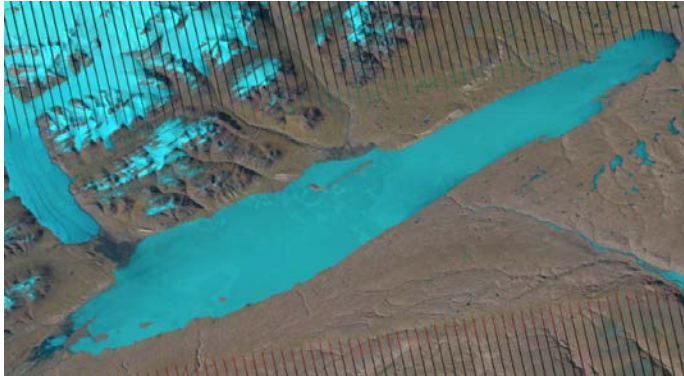


Landsat, 18 June 2010

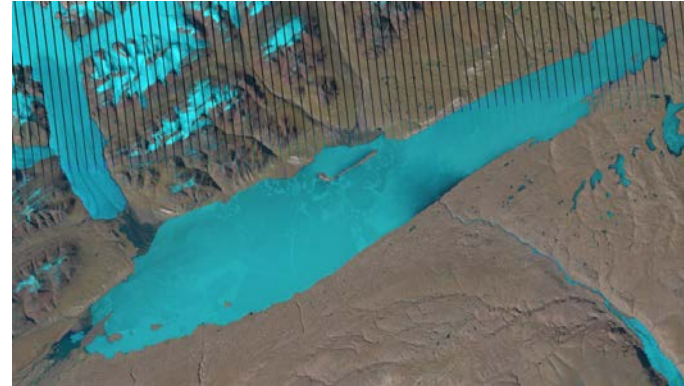


The Ice Season – cont.

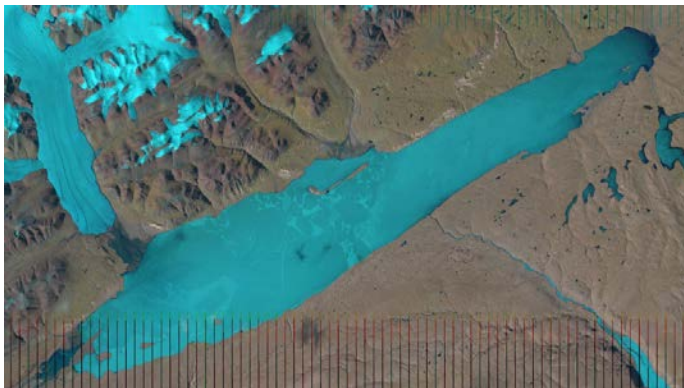
Landsat, 24 June 2010



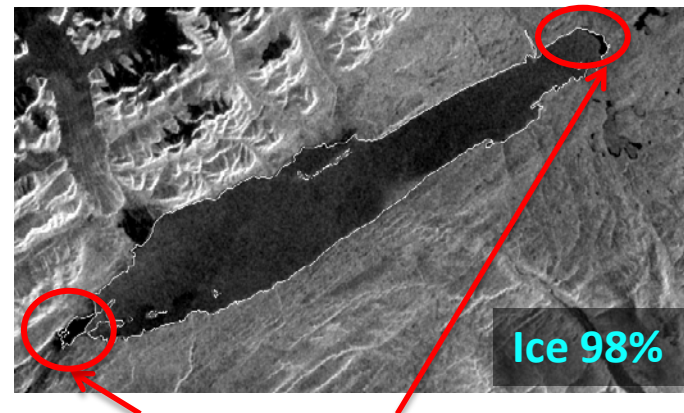
Landsat, 26 June 2010



Landsat, 29 June 2010



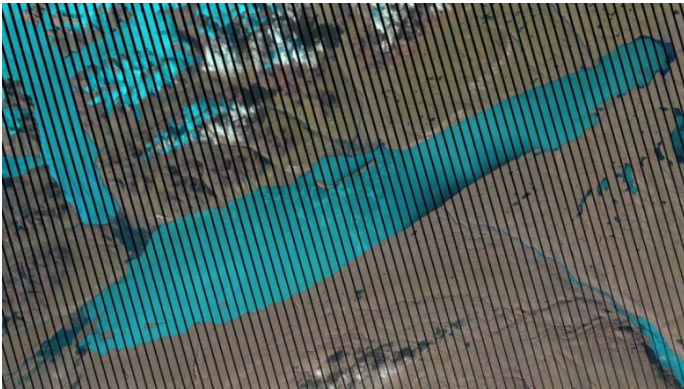
ASAR, 30 June 2010



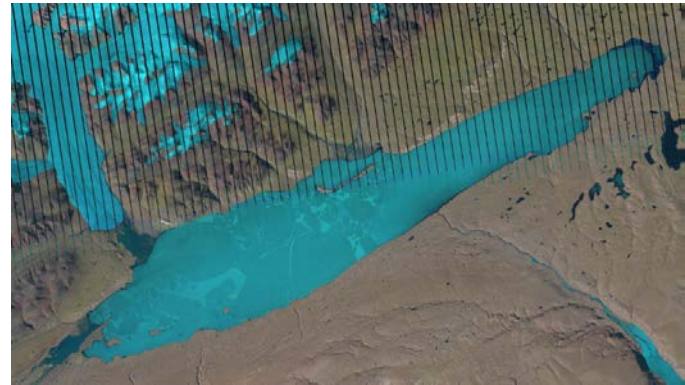
first detected melt onset with SAR
(24 days later than Landsat)

The Ice Season – cont.

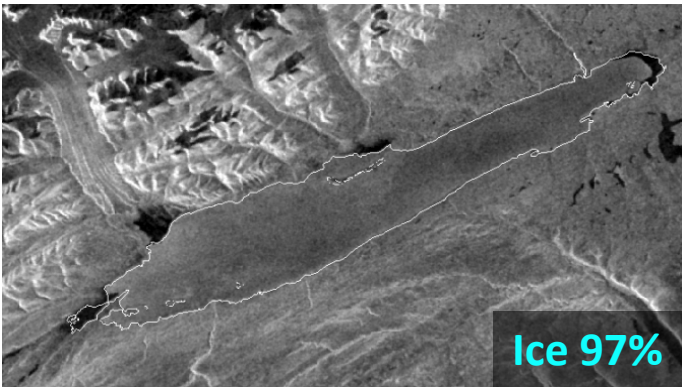
Landsat, 2 July 2010



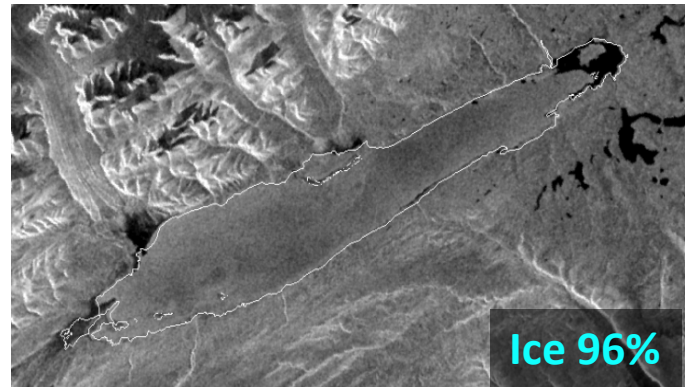
Landsat, 5 July 2010



ASAR, 7 July 2010



ASAR, 11 July 2010

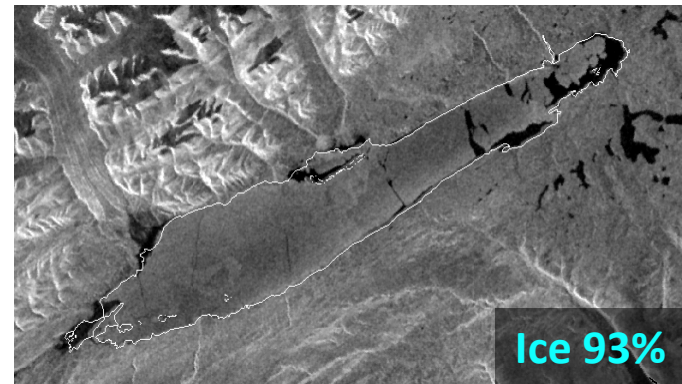


The Ice Season – cont.

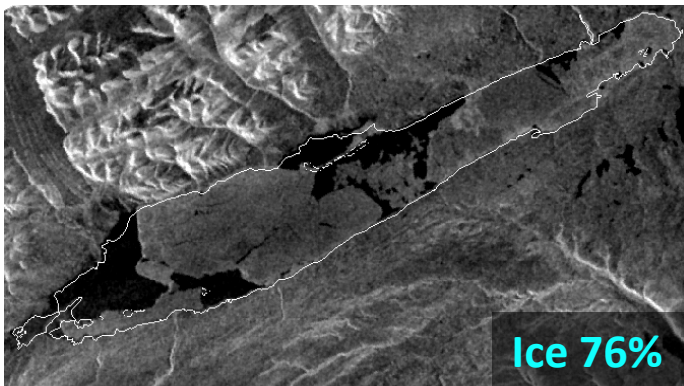
Landsat, 13 July 2010



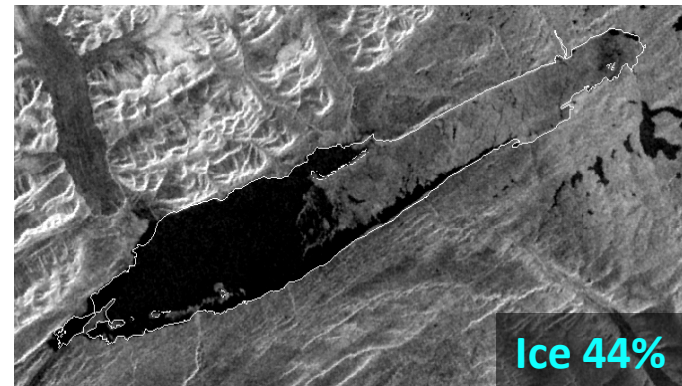
ASAR, 14 July 2010



ASAR, 17 July 2010

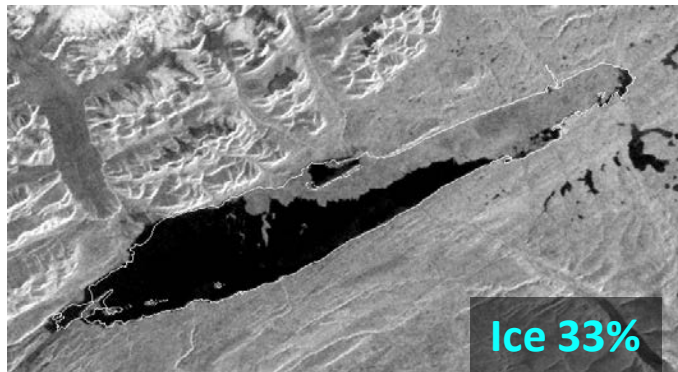


ASAR, 19 July 2010

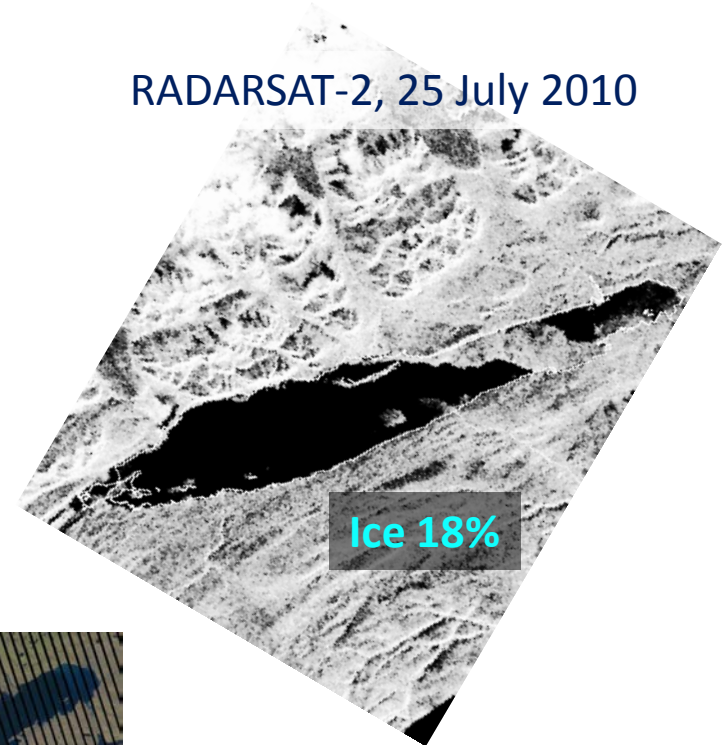


The Ice Season – cont.

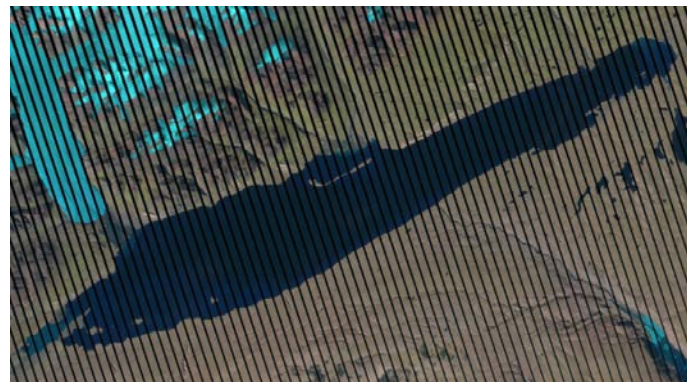
ASAR, 22 July 2010



RADARSAT-2, 25 July 2010

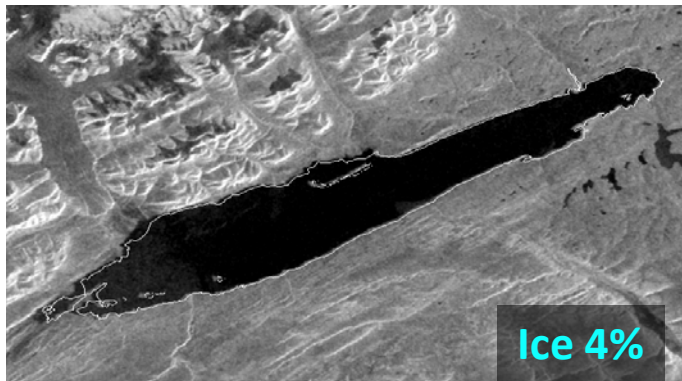


Landsat, 27 July 2010

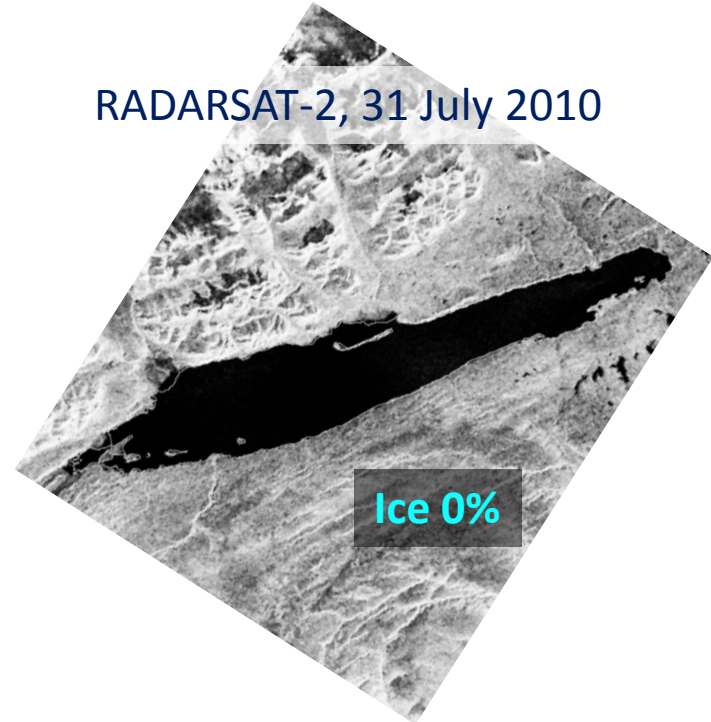


The Ice Season – cont.

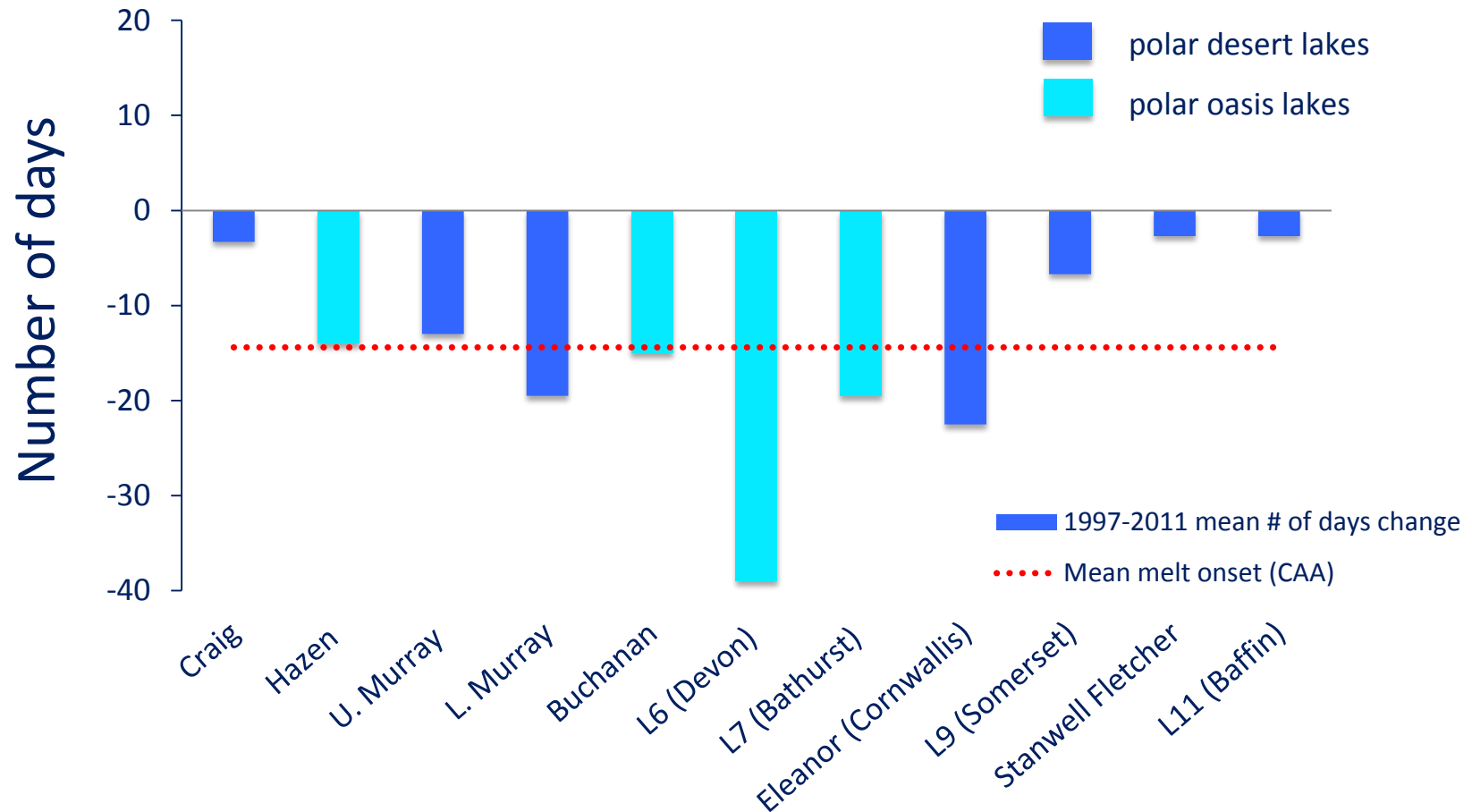
ASAR, 29 July 2010



RADARSAT-2, 31 July 2010

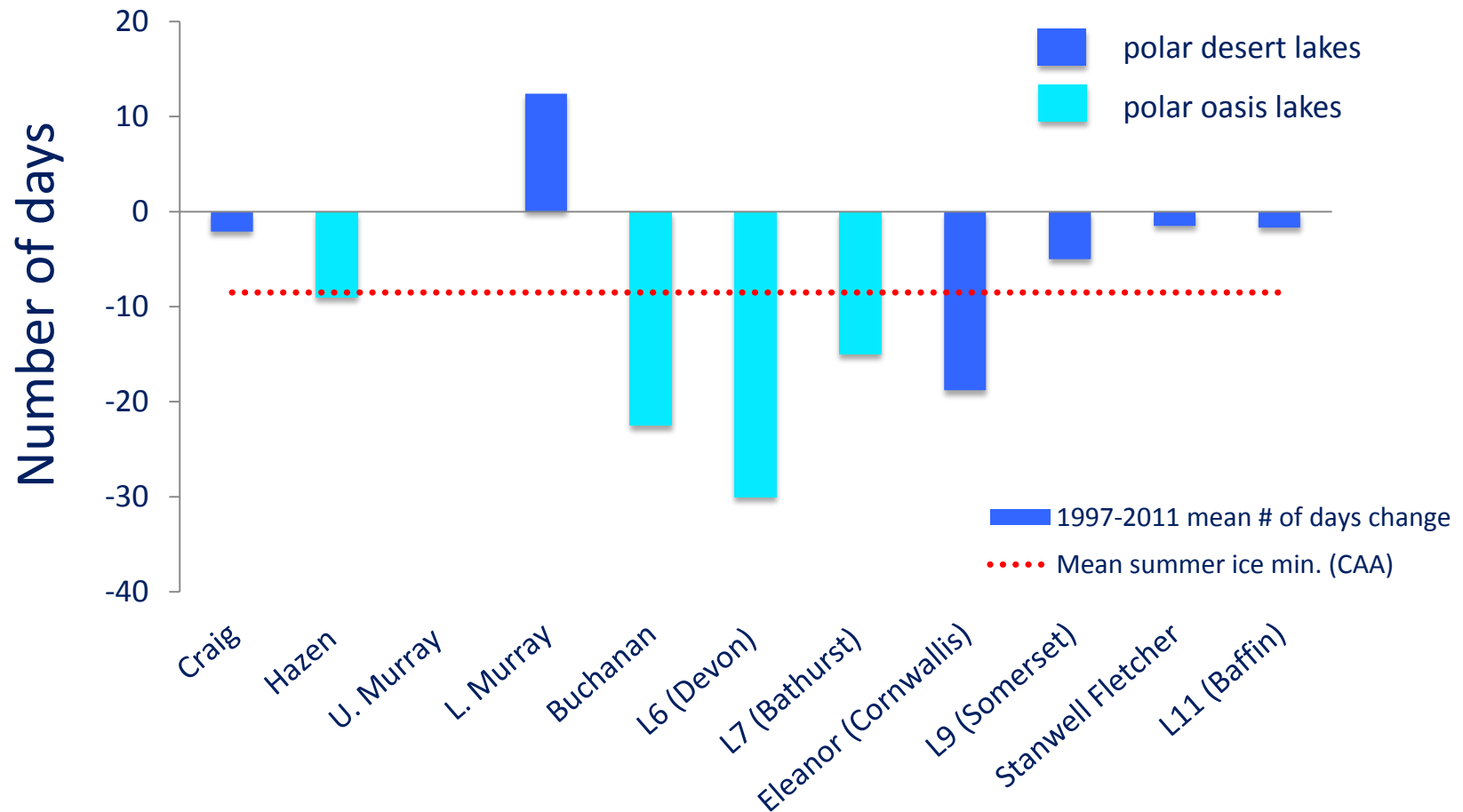


Melt Onset

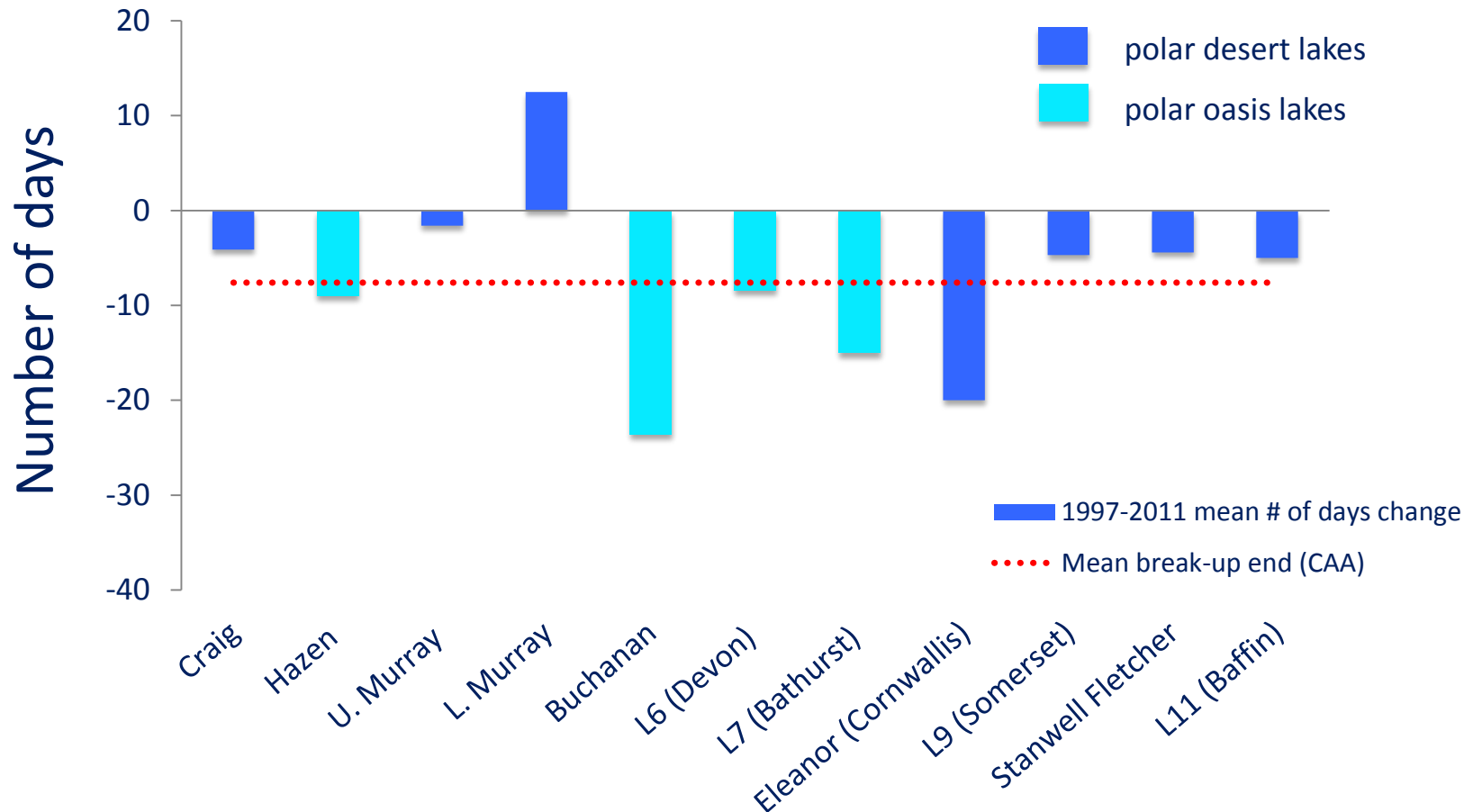


Surdu et al., under review

Summer Ice Minimum



Break-up End



Surdu et al., under review

- ❑ Ice conditions for **11 lakes** in the Canadian High Arctic were observed between **1997-2011** from combined ASAR, RADARSAT-1/2 and Landsat observations
- ❑ **Melt onset** started earlier for all 11 lakes
- ❑ **Summer ice minimum** occurred earlier for all lakes excepting Lower Murray Lake (Ellesmere Island)
- ❑ **Break-up ended** earlier for all lakes excepting Lower Murray Lake that experienced later break-up by 12.5 days
- ❑ **Perennial ice** was occasionally observed for 5 lakes

Arctic environment	Melt onset (# of days early)	Summer ice minimum (# of days early)	Ice-off (# of days early)	Perennial ice (occasionally)
Polar desert	3-23	2-19	2-20	3 lakes
Polar oasis	14-39	9-30	9-24	2 lakes

- ❑ **Spatial resolution** of the SAR beam modes (100-150 m) – does not capture melt onset for (small) lakes
 - melt onset observed with Landsat

- ❑ **Temporal resolution** of both SAR and optical sensors
 - transition from minimum ice to open water can occur within 1-2 days
 - optical and SAR acquisitions are at times 5 days apart

Acknowledgements

- ❑ This work was supported by a Discovery Grant from the Natural Sciences and Engineering Research Council of Canada (NSERC) to Claude Duguay.
- ❑ RADARSAT-1 images are copyright the Canadian Space Agency (CSA), 1997-2010.
- ❑ RADARSAT-2 Data and Products, © MacDonald, Dettwiler and Associates Ltd., 2008-2011, all rights reserved.
- ❑ ASAR data is copyright the European Space Agency (ESA), 2005-2011.
- ❑ Landsat images were provided by the U.S. Geological Survey.



Questions??