Integrating input from local, indigenous ice experts, a coastal ice observatory and measurements of ice decay into a forecast of coastal ice break-up

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Introduction

The Seasonal Ice Zone Observing Network (www.sizonet.org) collects data of use both to the scientific community and key stakeholders. Here, we present an example from the SIZONet observatory site at Barrow and show how these two information needs may overlap in a coastal Alaska setting. Decay and break-up of coastal sea ice are important to a range of physical and biological processes. They also control the access to and from the coast by boat, important for subsistence hunters and industry in coastal Alaska. Ice observations by Iñupiaq ice experts and informal interviews with other knowledgeable ice users helped define the key stages of break-up. They also helped identify the aspects of break-up important to ice users, namely the point at which boats can be launched through any potentially remaining grounded ice ridges.

Ice seasons and ice use in three Arctic communities

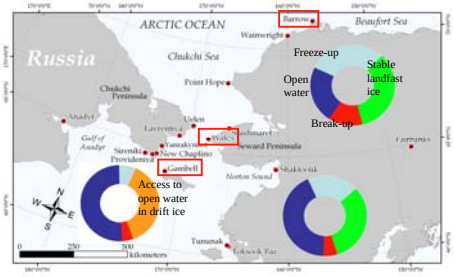

Fig. 1. Ice season data for 2006/07 from SIZONet observations by local sea ice observers Leonard Apangalook (Gambell), Joe Leavitt (Barrow) and Winton Weyapuk Jr. (Wales).

- Coastal ice observations in collaboration with Sea Ice Knowledge & Use (SIKU) IPY Project led by Igor Krupnik and collaborators
- Indigenous ice experts observe ice phenomena in the context of ice use by their community; SIKU active in more than a dozen communities (observations, dictionaries, etc.)
- SIZONet developed database for archival and analysis of observations in conjunction with geophysical data acquisition (see map)

Defining ice decay and break-up

Examination of ice observatory data (coastal radar and webcam, www.gi.alaska.edu/BRWICE) and satellite imagery in conjunction with observations by local experts helped chart the progress of ice decay and break-up during the past decade.

Barrow ice observatory – Break-up dates 2000-2009

Year	Webcam meltponds	Air temperature indicator for melt	Albedo <0.65	Shore-fast ice mode	Shore-fast ice starting	Pressure ridges period
2000	7 June	6 June	11 June	drift-out	10 July	29–31 July
2001	1 June	11 June	13 June	drift-out	5 July	7 July
2002	21 May	22 May, 4 June	19 May	drift-out	30 June	1–15 July
2003	5 June	18 May, 3 June	4 June	break-out	25 June	24 June
2004	n/r	19 May, 5 June	4 June	break-out	18 June	18 June
2005	n/r	9 June	11 June	drift-out	8 July	13–16 July
2006	n/r	24 May, 5 June	8 June	melt-out	6 July	4–9 August
2007	n/r	3 June	5 June	break-out	27 June	27 June
2008	n/r	23 May, 3 June	6 June	drift-out	8 July	17–19 July
2009	n/r	29 Apr, 18 May, 24 May, 1 June	2 June	drift-out	11 July	15–18 July

Table 1. Bounds on break-up period for pressure ridges are conservative limits. n/r indicates that the observed time of melt pond formation is deemed not representative for this study due to the location of the webcam.

- Onset of ice surface melt (appearance of ponds, low albedo at adjacent ARM tundra site) defines start of ice decay
- Three modes of ice break-up: complete in situ melt-out, melting with gradual eventual removal of ice, break-out driven by dynamic events
- Break-up: starts with level ice melted out (access to ocean), ends with grounded pressure ridges removed

Satellite imagery depicting break-up 2007

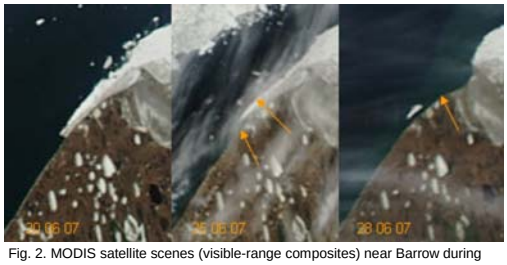

Fig. 2. MODIS satellite scenes (visible-range composites) near Barrow during break-up 2007. Images show an area approx. 30 km x 40 km in size.

- 20 June: Lead is open & landfast ice is still in place
- 25 June: Some ice lost immediately south of Barrow & at the landfast ice edge
- 28 June: Landfast ice completely broken out; grounded pressure ridge linger for few days off town

Observations from local ice experts in 2007 and 2009

18 June 2007 - Shore ice took off just 4mi west of Barrow, ice more rotten, ice taking off early this year. I boat out right now for bearded seal.

24 June 2007 - No change ice still over 10 mi out. Men hunting seal while ice here. Ice takes off early this year, last year mid July.

27 May 2009 - Whaling was stopped yesterday, unsafe ice, people been Falling though the ice, lots of water in front of town on the shore fast but lot better when you leave town area.

9 July 2009 - Very open water, ice pack further out. Seal hunters going to the Pt. [Point Barrow] to get out [to open water]. 15mi to small ice floes. Elson lagoon not possible w/ boat yet

- Local ice users in Barrow rely on access to offshore drifting ice to hunt bearded seal and walrus
- Coastal ice first needs to decay to a stage (here defined as start of break-up) that allows boats to be launched
- Ideal from hunters' perspective is a quick break-up with lingering offshore ice

Factors controlling ice decay: Ice albedo evolution

Observations of ice decay (Table 1) and time series of ice albedo (Figs. 3 & 4) can help identify the controls of ice decay that eventually lead to break-up. Ice mass-balance data show that presence of snow largely shields the ice cover from warming and onset of decay. This is well reflected in ice albedo time series collected along profiles in conjunction with surface topography measurements.

Time series of total albedo

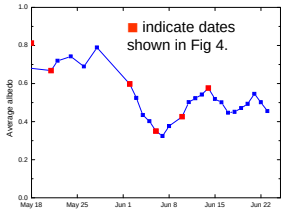

Fig. 3. Albedos measured using a Kipp and Zonen albedometer. Values are averaged over the 200-m-long North albedo line at the Barrow ice mass balance site. The red point on the y axis corresponds to data collected on 24 April before onset of melt.

Spatio-temporal variation of albedo

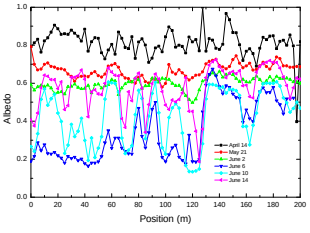

Fig. 4. Wavelength-integrated albedos along the line on selected dates (red squares in Fig. 3). The albedo variations along the line are primary a result of the spatial distribution of melt ponds.

Fig. 5. Aerial photograph of shorefast, first-year ice at Barrow, AK on 8 June, 2009.

- Surface albedo data show that onset of pond formation is the key event that starts ice decay
- Ponding sets in roughly around the same date (June 5) at Barrow
- Low-albedo ponds initially flood large fraction (>50 %) of ice area (June 3-7, Fig. 3), with associated increases in surface melt rate and interior ice warming
- In later stages of melt, ice partly drains and further melt driven largely by solar heating

Tracking and forecasting ice decay and break-up

Based on this analysis we developed a semi-empirical approach for forecasting ice break-up. The method relies on the cumulative and average down-welling shortwave flux to chart the progress of ice decay (Fig. 6). This approach provides insight into the progression of different melt season "types", such as the sunny and light ice season years of 2004 and 2007 with unusually early break-up in mid/late June. In 2009 this model was forced with 14-day forecasts from the Weather and Research Forecasting (WRF) model. We obtained remarkably accurate and consistent forecasts for the break-up date (within ±2 days of the observed event, Fig. 7).

Tracking ice decay based on solar radiation

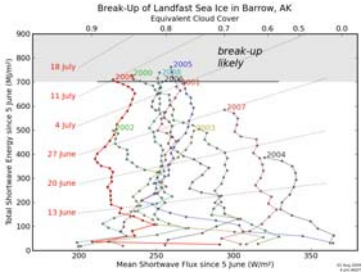

Fig. 6. Integrated incoming hemispheric shortwave radiation measured at the ARM site between 5 June and break-up. Lines are colored to guide the eye.

Break-up date forecasts, 2009

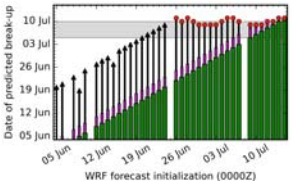

Fig. 7. Break-up forecasts for 2009 in relation to initialization time of the WRF model. Circles indicate the expected break-up dates, triangles denote the end of a WRF forecast without expected break-up. Vertical bars: Green/thick - ARM data; purple/medium - estimate based on observed cloud cover; black/thin - WRF runs. The horizontal lines bounding a grey box indicate the range of melt-out or drift-out break-up dates between 2000 and 2008 (2002 not shown).

Conclusions

- Main modes of coastal landfast ice break-up at Barrow (and elsewhere?): melt-out, drift-out, break-out
- Locals mostly interested in level ice melt-out providing access to offshore ice by boat
- Ice decay onset triggered by first melt ponds (around June 5) marking low-albedo early melt phase
- Cumulative & mean surface shortwave flux good ice-decay indicators for tracking & forecasting break-up
- WRF 14-day model runs remarkably accurate (+/– 2 d) in forecasting ice break-up: Fortuitous anomaly?

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