Ice regime of Eurasian lakes

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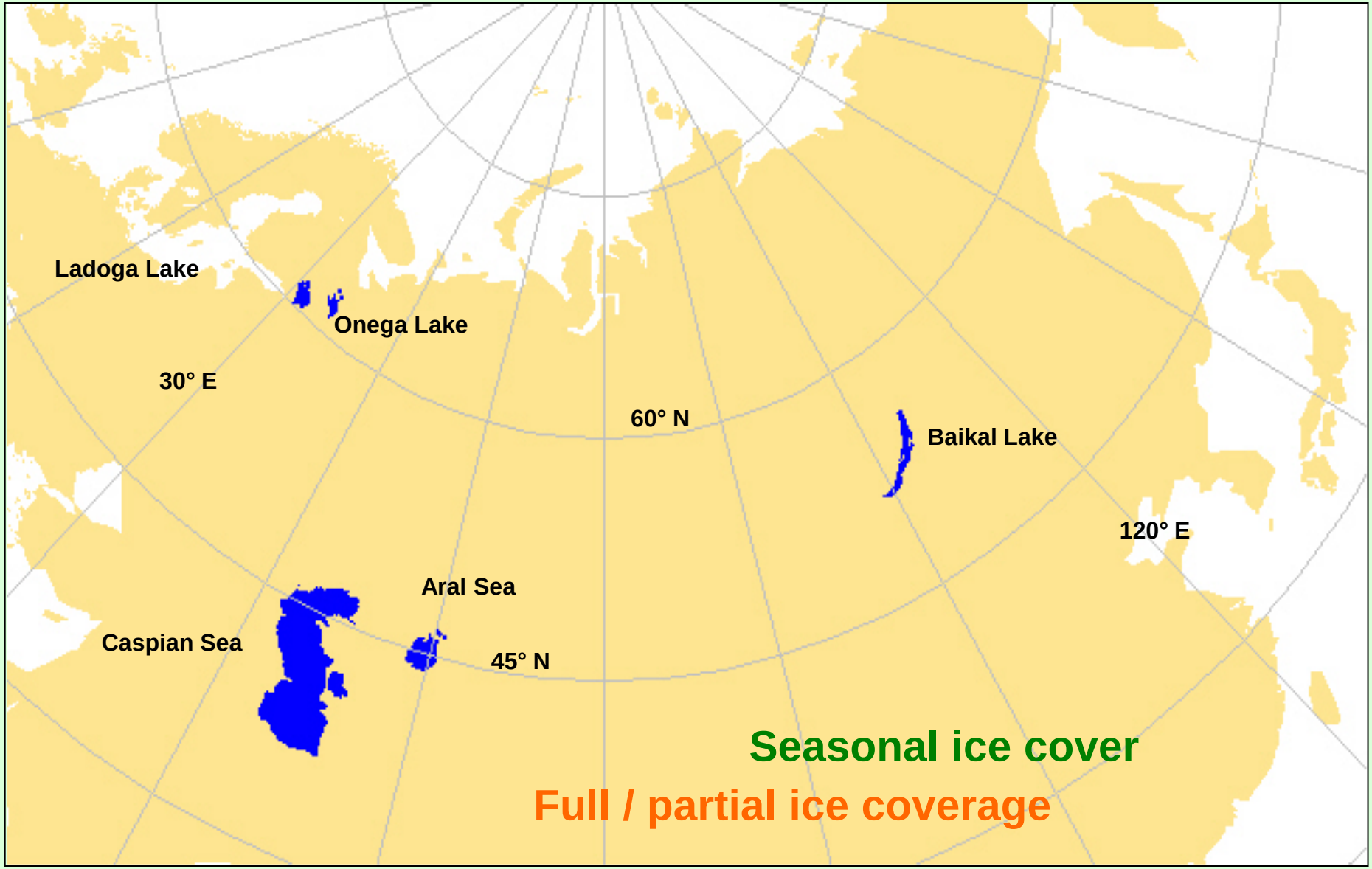
CCT TSI Atelier
Altimétrie et Glaciologie, 2 June 2016, Toulouse

Study areas

Five largest Eurasian water bodies (salt/fresh)



Completing the view: dedicated field campaigns

"Can't rely on anyone these days, you have to do everything yourself..."
(Joker in "The Dark Knight", 2008)

Dedicated projects:

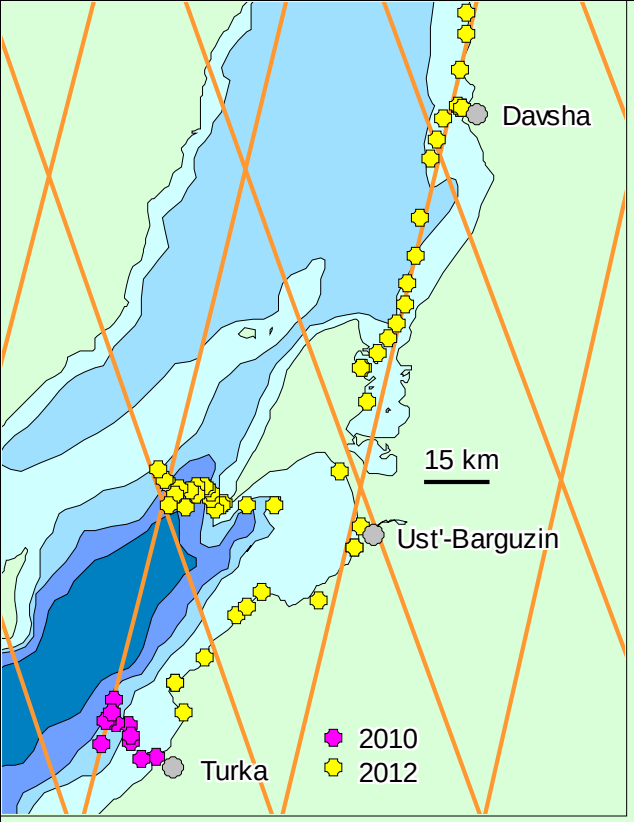
2011- **CNES TOSCA** "Lakes"

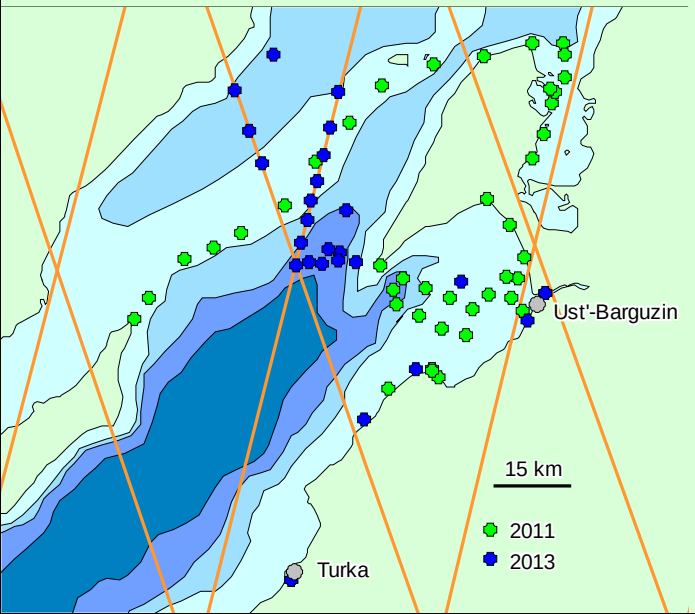
2012-15 **PICS CNRS-Russia** - "BaLaLaICA - BAikal and LAdoga LAkes - Integrated Cooperation Activities

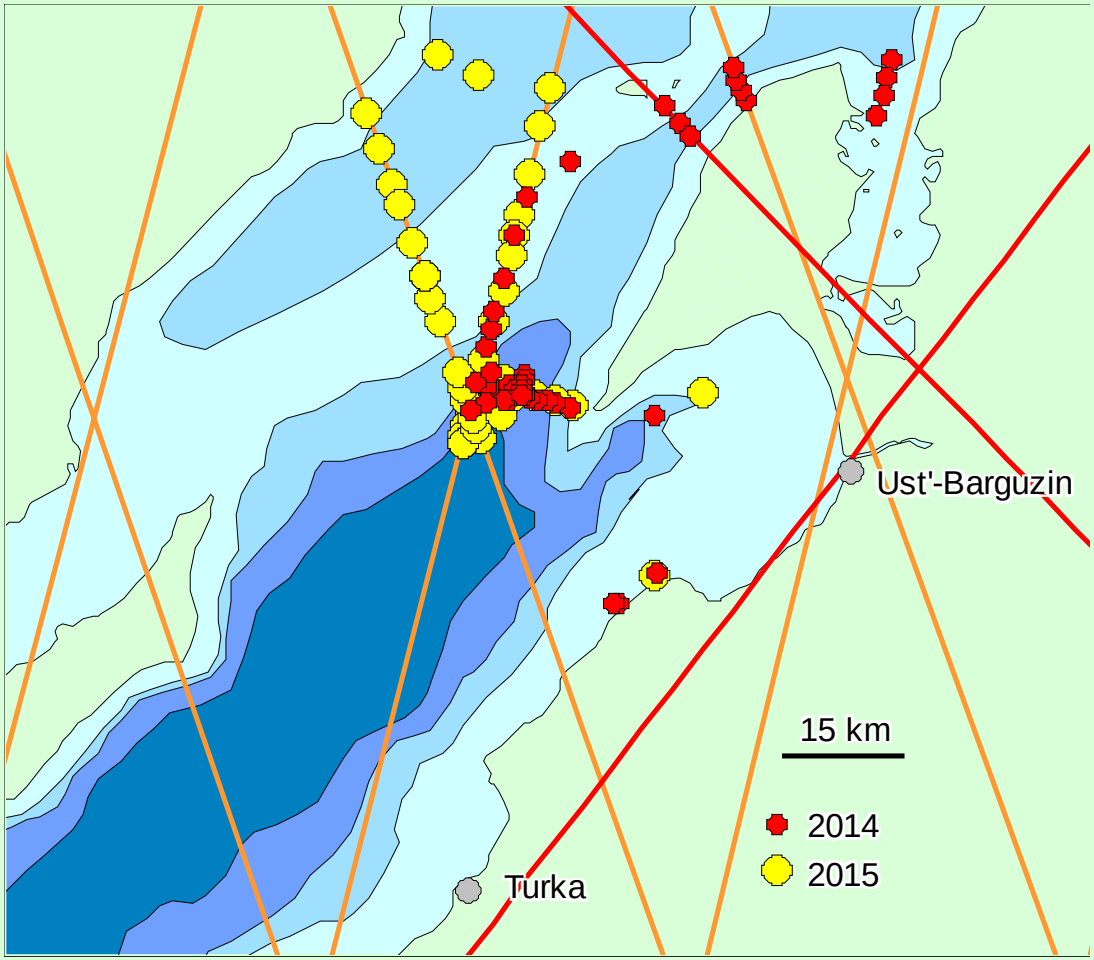
2012-15 **RFBR** PI(FR) Project "Studies of Ladoga and Baikal lakes"

2016-17 **ERA.Net RUS Plus** Project "ERALECC"

Field work - Baikal

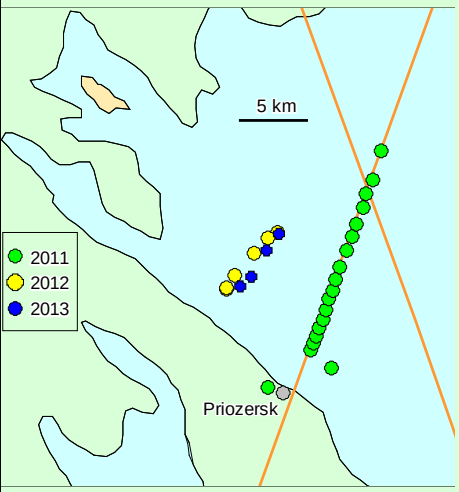


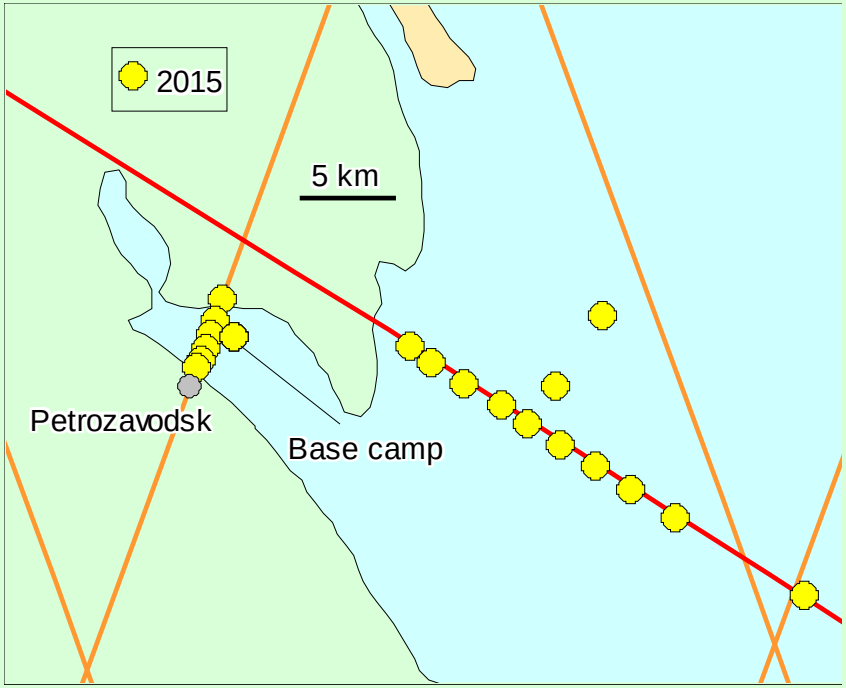


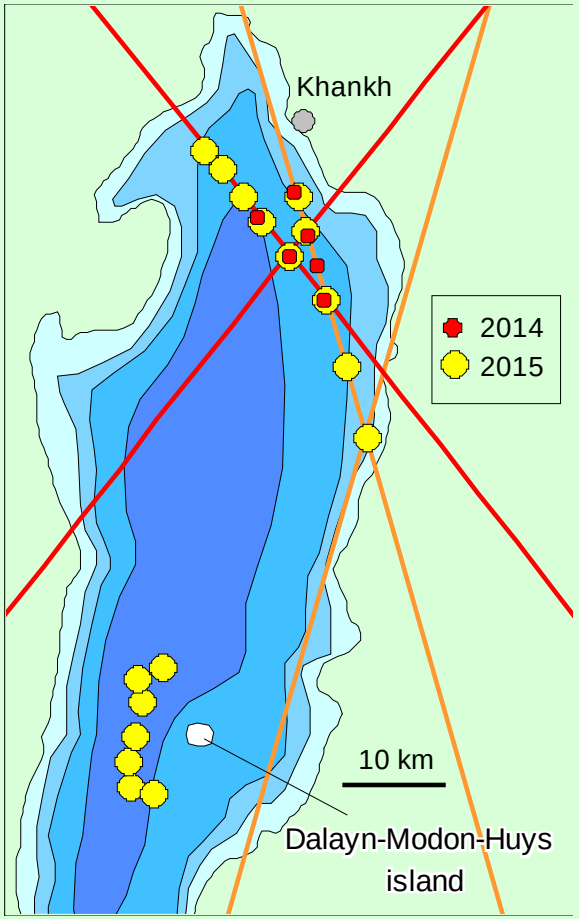


High spatial sampling along-track

Field work - Ladoga, Onega and Hovsgol







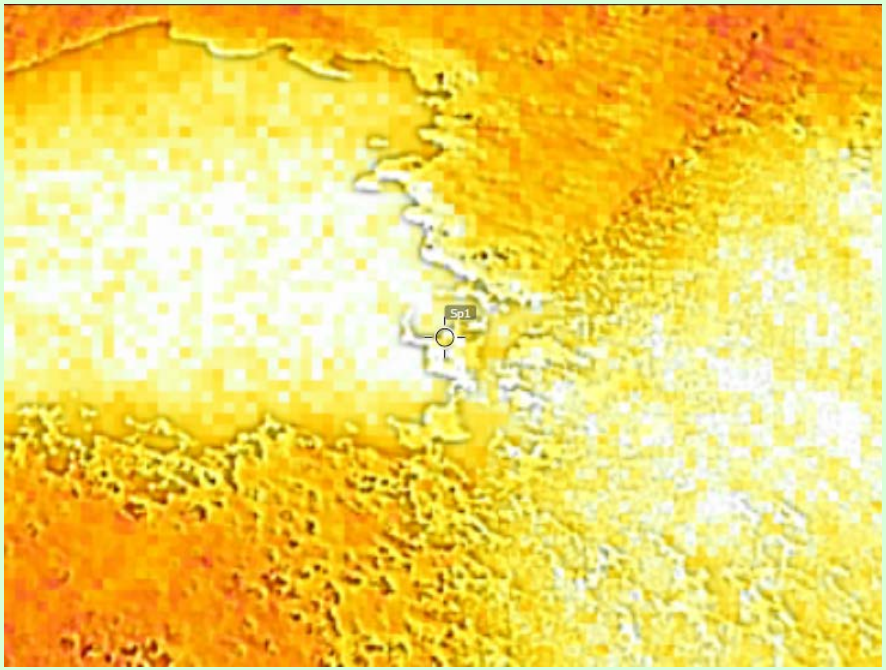
Swiss-Russian project “Lake Ladoga”

Data

Number of stations for field trips per year and for each lake, and parameters measured (IT - ice thickness, IS - ice structure, SD - snow depth, CTD - CTD measures, FB - freeboard, C - currents, CM - current meter mooring, SS - spectral signature, TIR - thermal infra-red measurements, SfM - Structure from motion, TM - thermal moorings)

Year		Baikal	Ladoga	Hovsgol	Onega
2010	IT, IS, SD	10			
2011	IT, IS, SD	52	20		
2012	IT, IS, SD, CTD	57	7		
2013	IT, IS, SD, CTD	27	5		
2014	IT, IS, SD, CTD, FB, C	46	no ice	6	
2015	IT, IS, SD, CTD, FB, C, SS, TIR, SfM	43	no ice	17	22
2016	IT, IS, SD, CTD, FB, C, CM, TM	37 (Feb) 17 (Mar)	no ice	17	22
Total		**289**	**32**	**40**	**44**

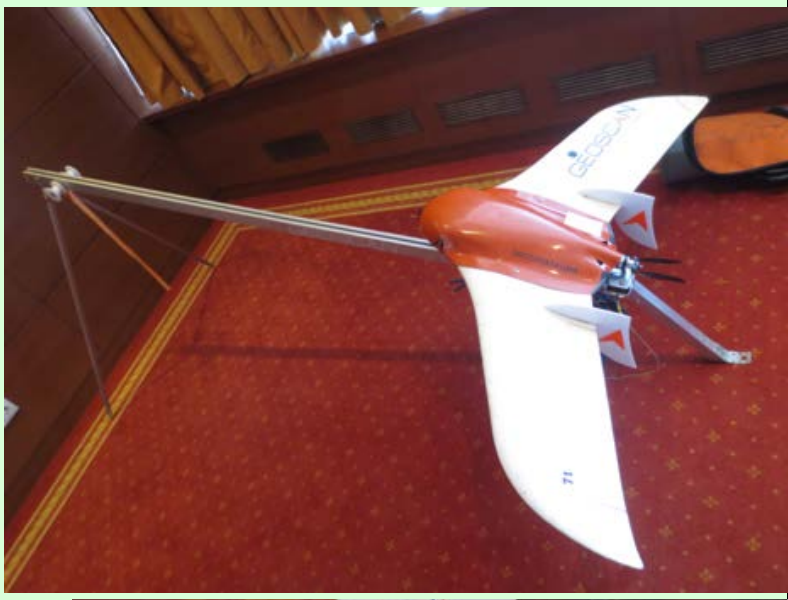
TIR measures



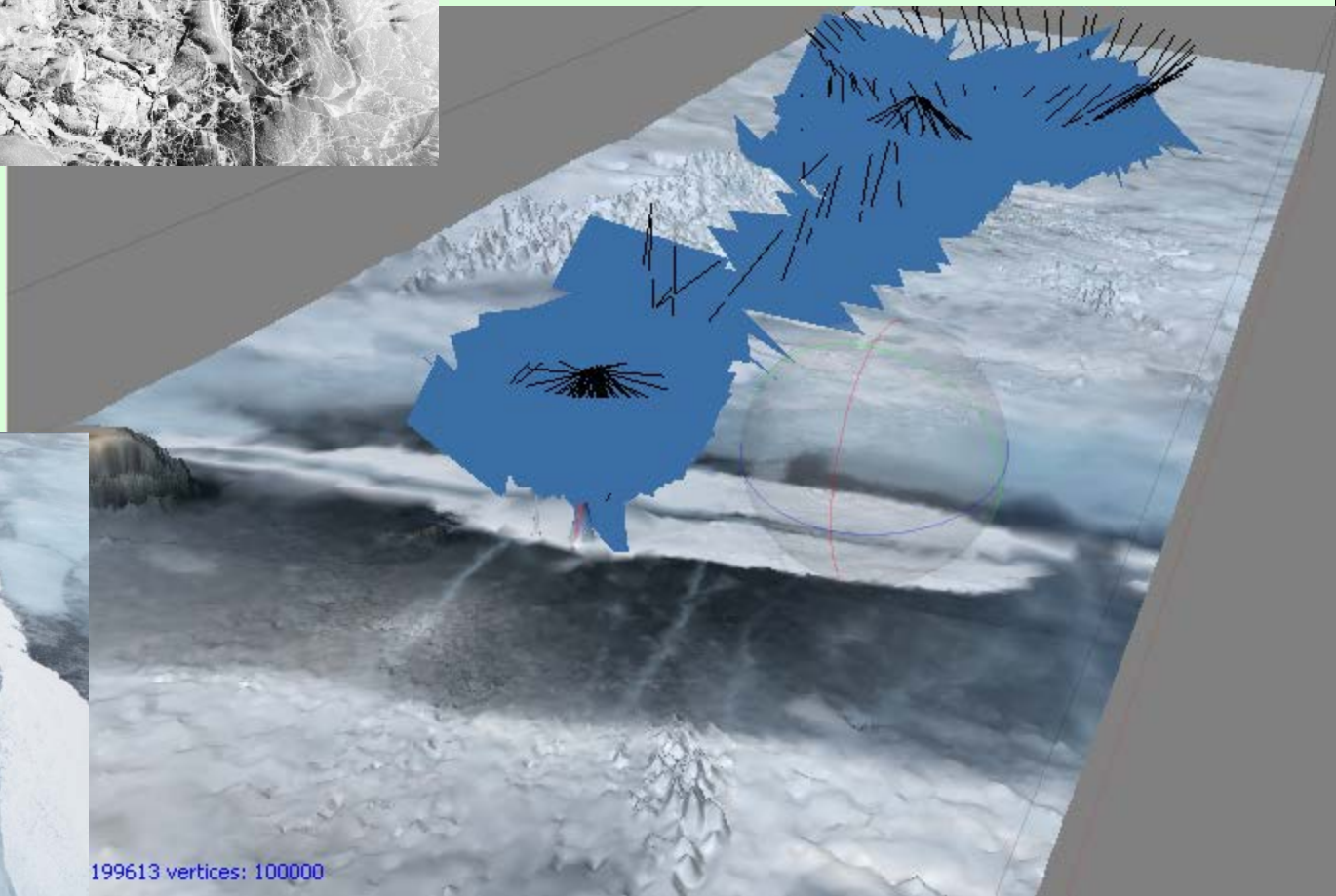
Lac Onega: l'image en visible (a) et en infra-rouge thermique (b, blanc - plus chaud, rouge - plus froid) pour une surface de la glace qui combine la glace cristalline (noire), glace blanche et la neige.

Drone imagery

L'image (camera en visible) de camp de base sur le lac Onega faite a partir d'un drone. (c) Y. Akhtman (EPFL).

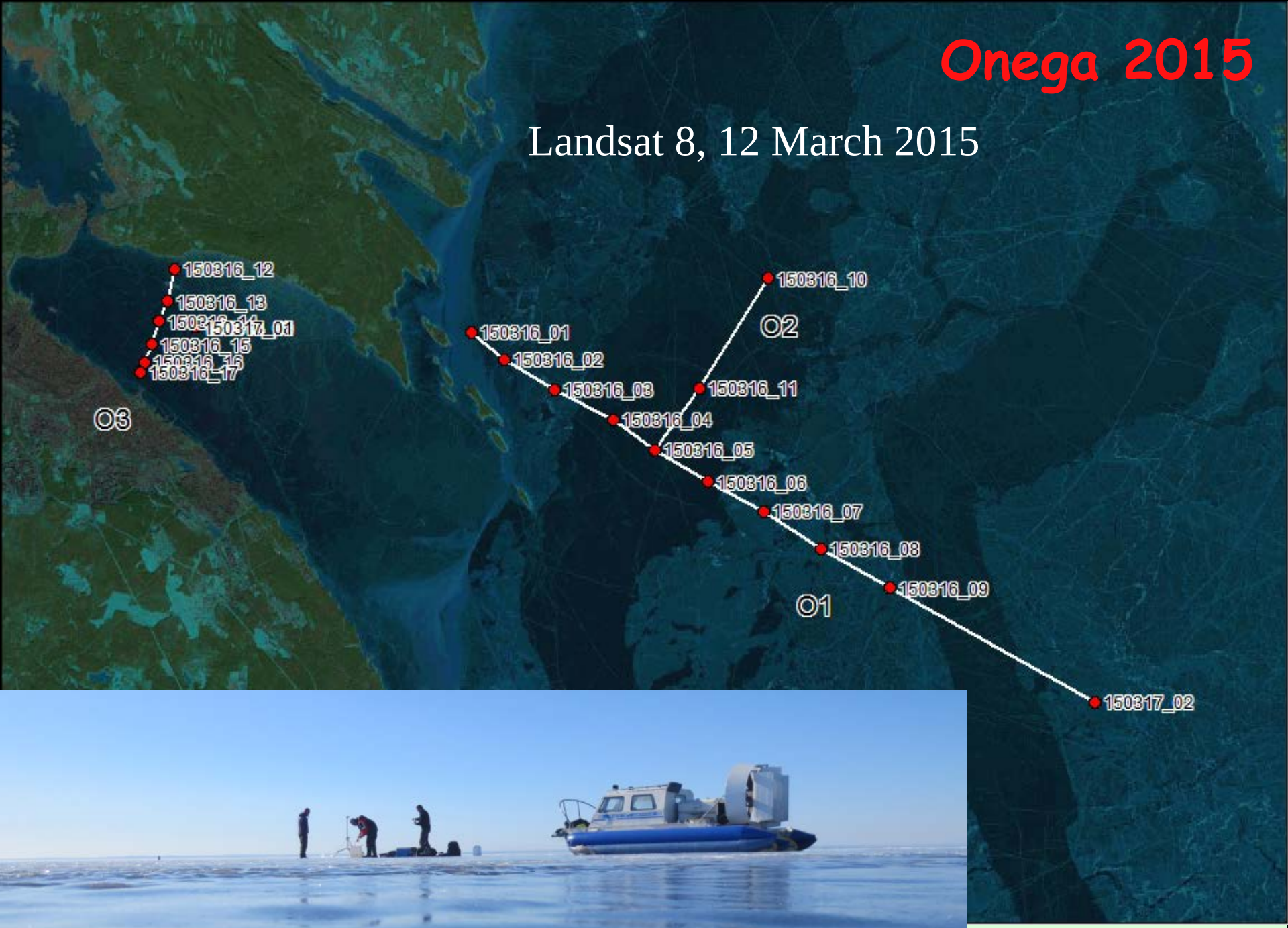


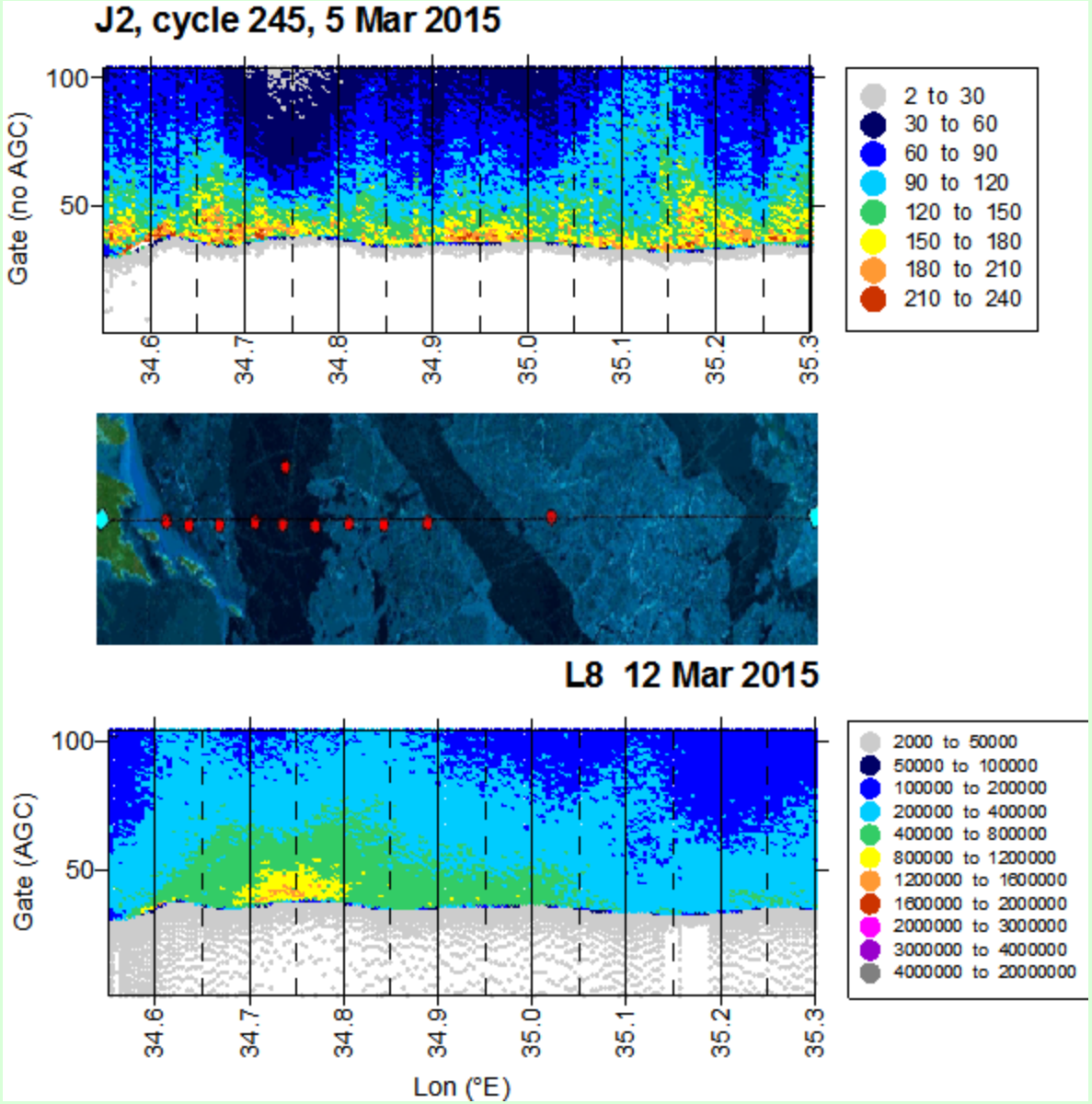
SfM (Structure from Motion) = DEM

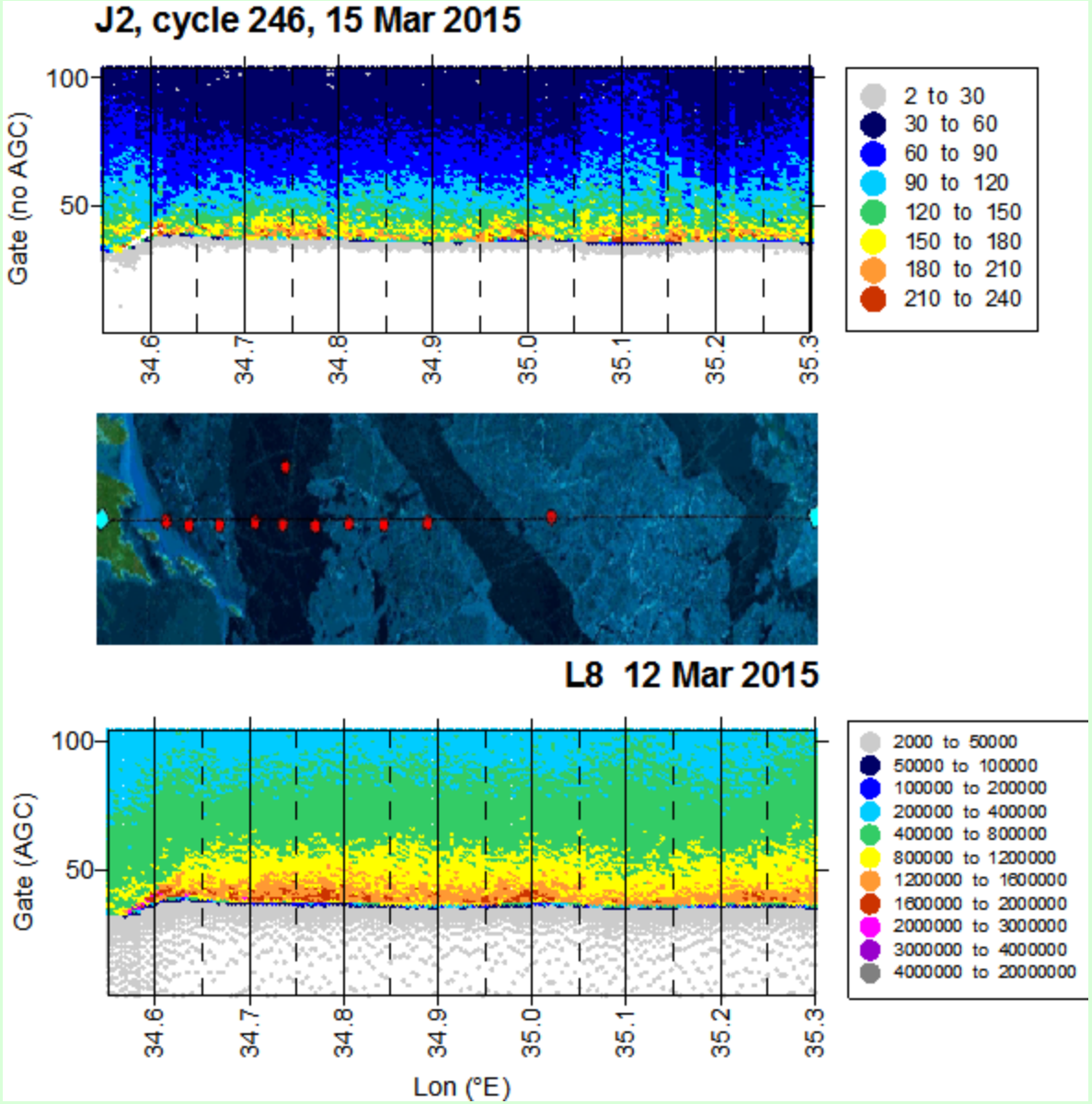


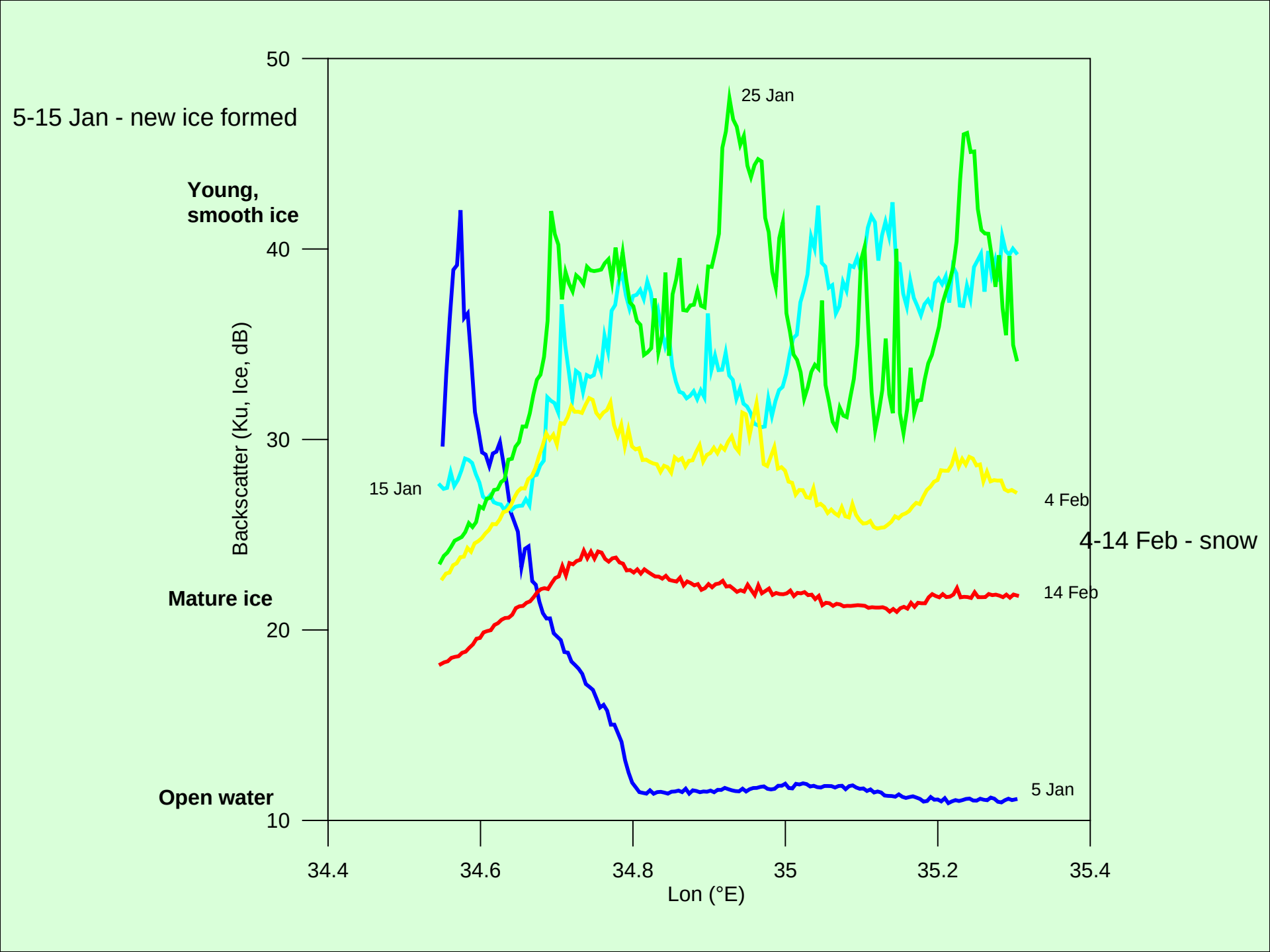
Onega 2015

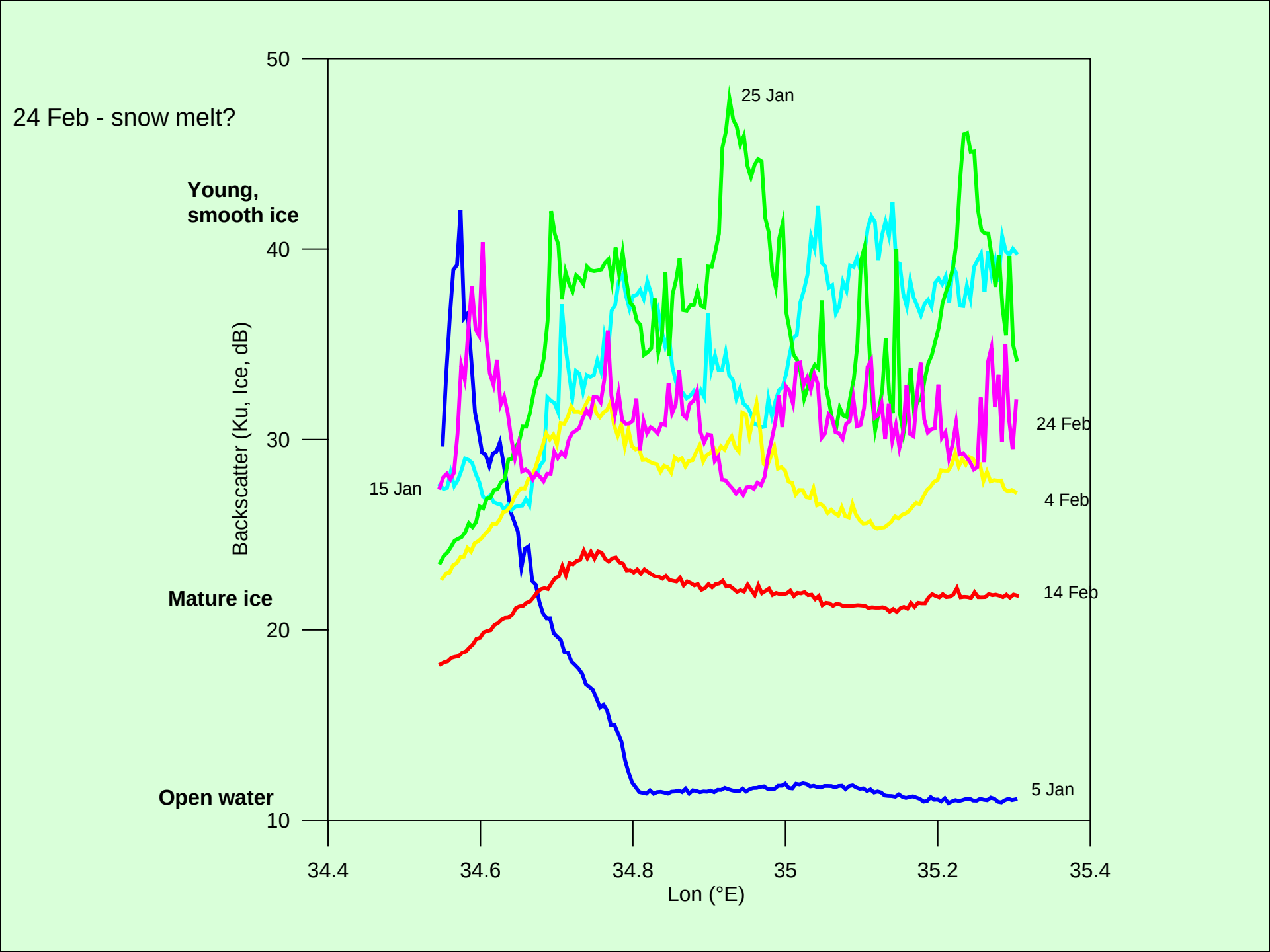
Landsat 8, 12 March 2015

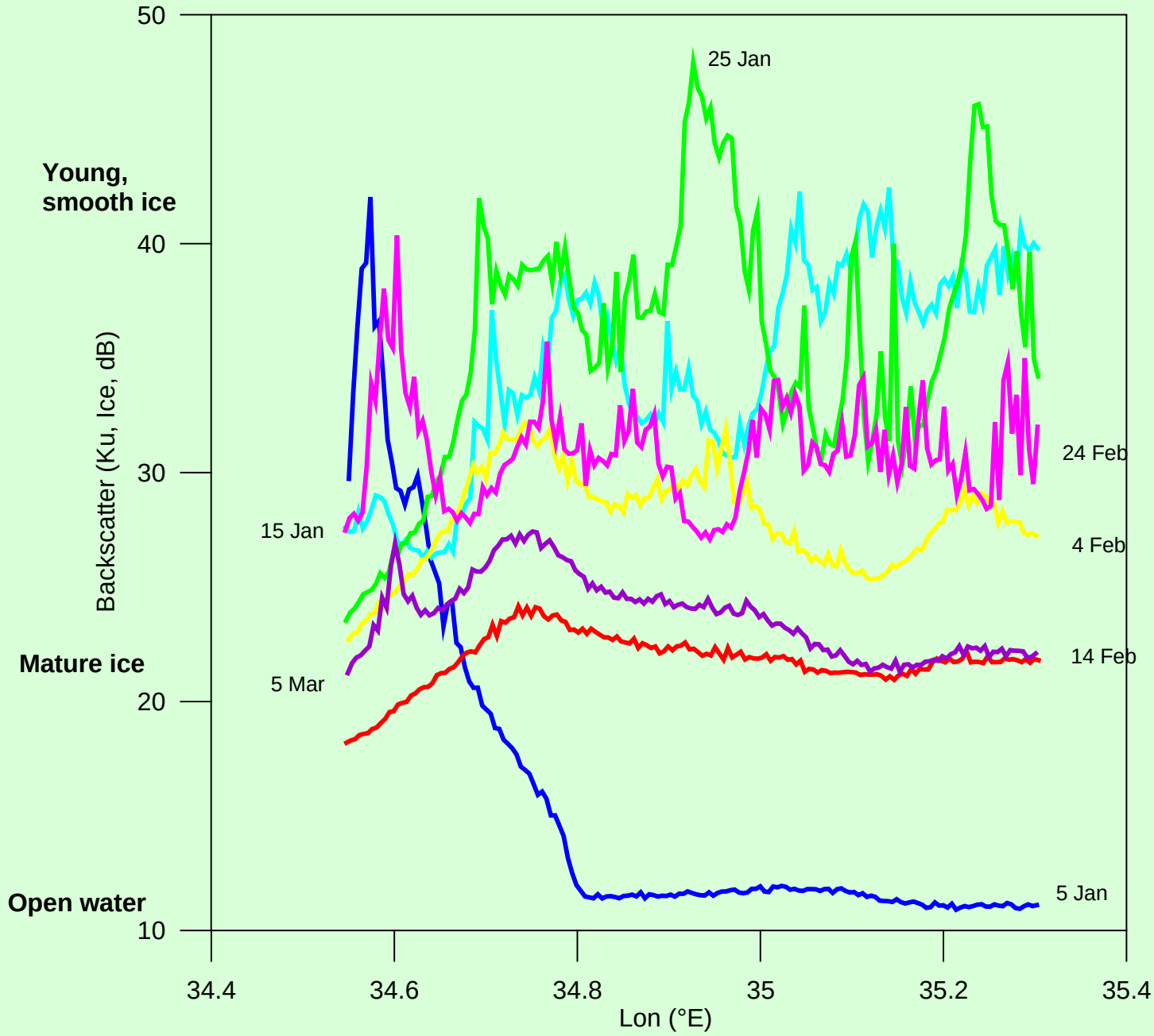


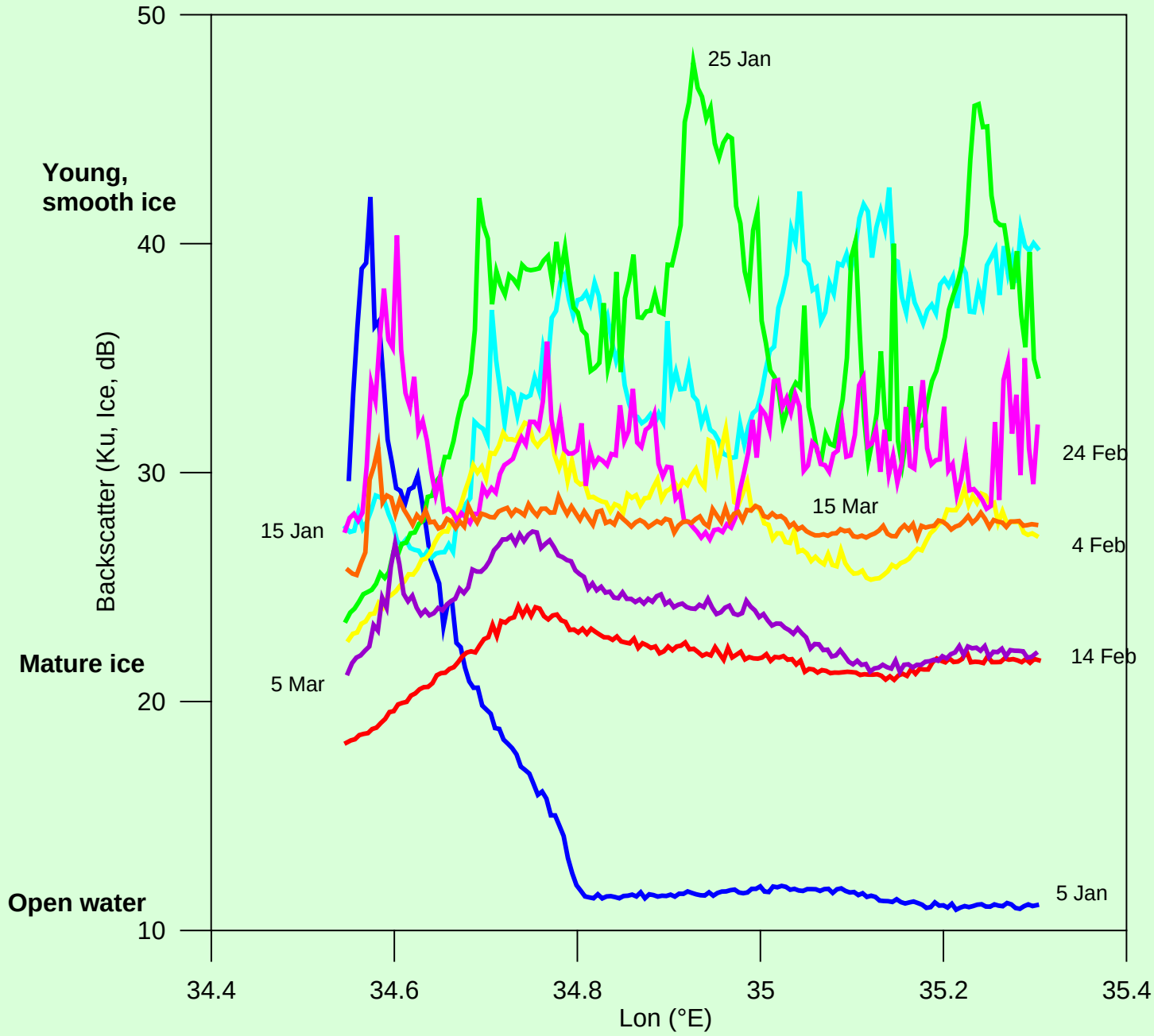

J2, cycle 245, 5 Mar 2015
Gate (no AGC)
100
50
34.6
34.7
34.8
34.9
35.0
35.1
35.2
35.3
2 to 30
30 to 60
60 to 90
90 to 120
120 to 150
150 to 180
180 to 210
210 to 240
L8 12 Mar 2015
Gate (AGC)
2000 to 50000
50000 to 100000
100000 to 200000
200000 to 400000
400000 to 800000
800000 to 1200000
1200000 to 1600000
1600000 to 2000000
2000000 to 3000000
3000000 to 4000000
4000000 to 20000000
Lon (°E)

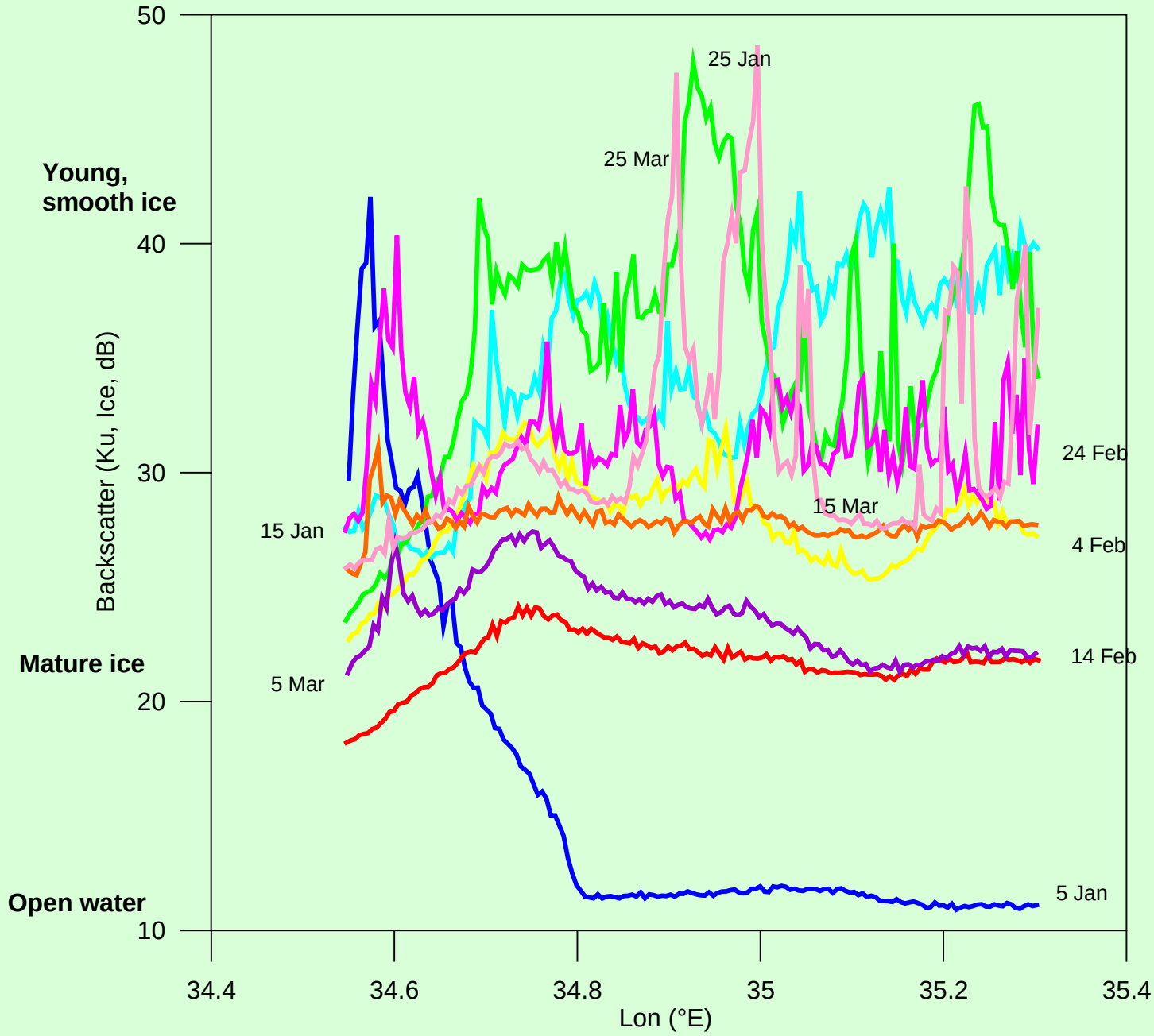

J2, cycle 246, 15 Mar 2015
Gate (no AGC)
100
50
34.6
34.7
34.8
34.9
35.0
35.1
35.2
35.3
2 to 30
30 to 60
60 to 90
90 to 120
120 to 150
150 to 180
180 to 210
210 to 240
L8 12 Mar 2015
Gate (AGC)
100
50
2000 to 50000
50000 to 100000
100000 to 200000
200000 to 400000
400000 to 800000
800000 to 1200000
1200000 to 1600000
1600000 to 2000000
2000000 to 3000000
3000000 to 4000000
4000000 to 20000000
Lon (°E)

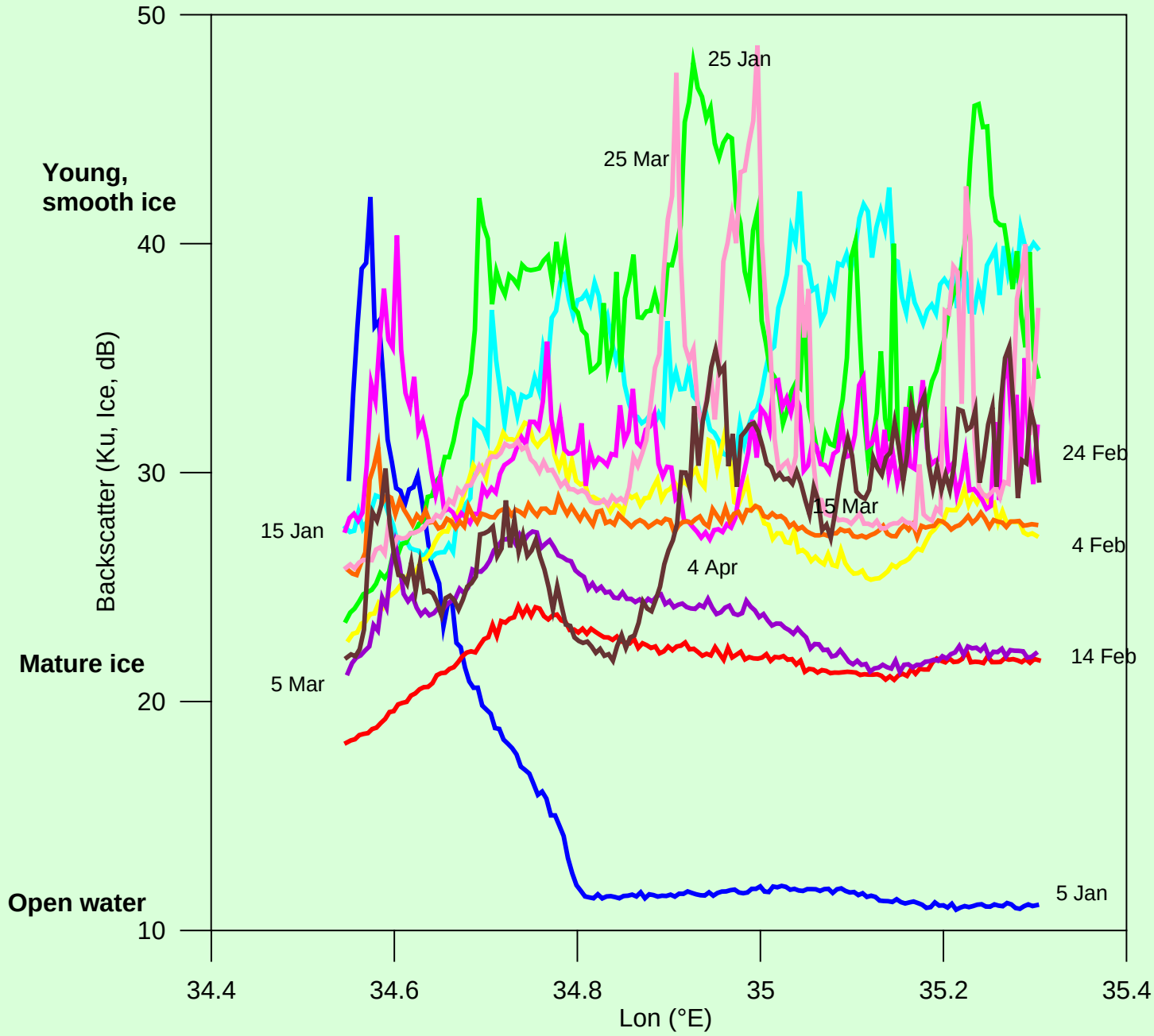

5-15 Jan - new ice formed
Young, smooth ice
Mature ice
Open water
Backscatter (Ku, Ice, dB)
50
40
30
20
10
25 Jan
15 Jan
4 Feb
14 Feb
5 Jan
4-14 Feb - snow
34.4
34.6
34.8
35
35.2
35.4
Lon (°E)

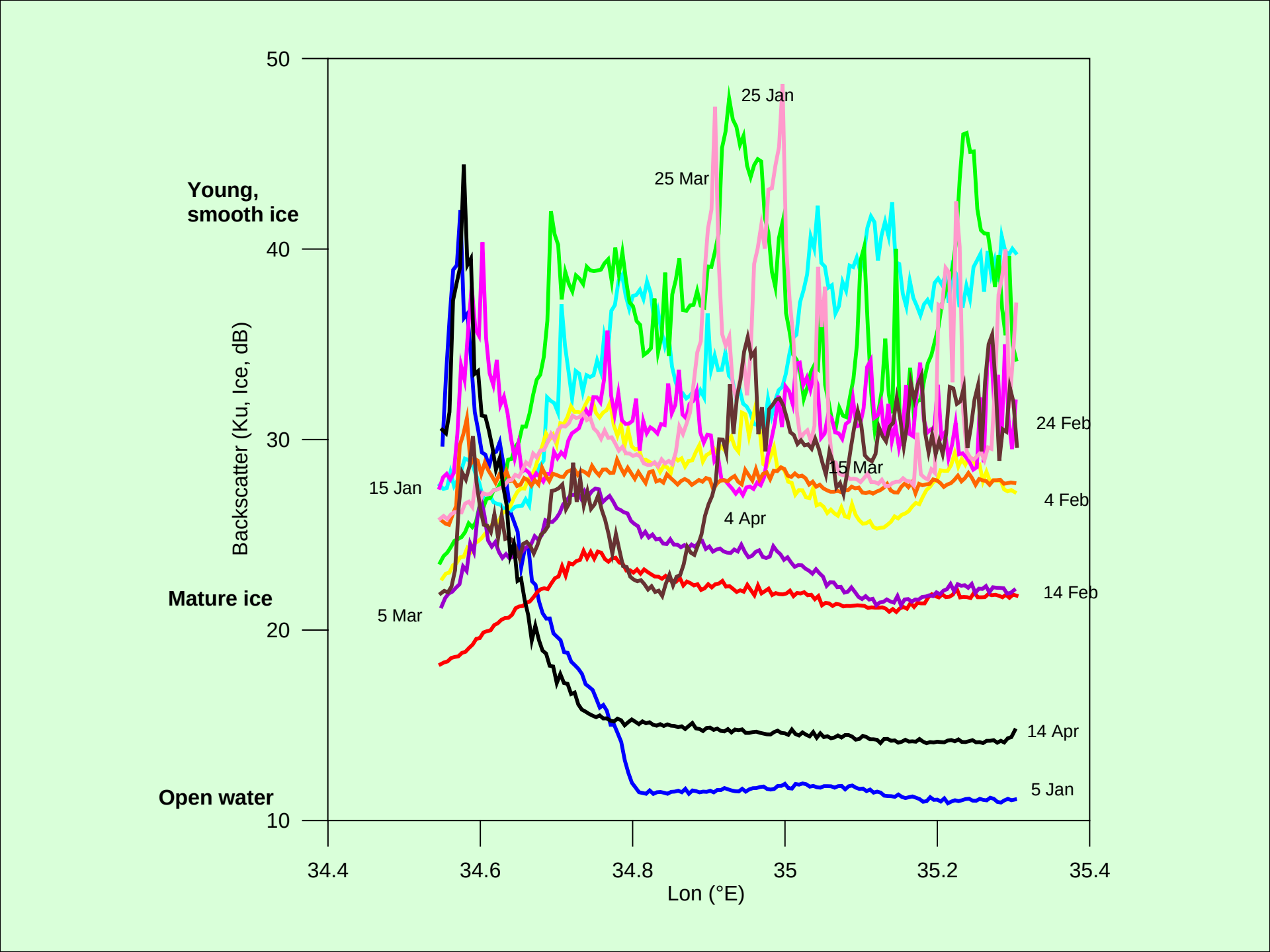

24 Feb - snow melt?
Young, smooth ice
Mature ice
Open water
Backscatter (Ku, Ice, dB)
50
40
30
20
10
34.4
34.6
34.8
35
35.2
35.4
Lon (°E)
25 Jan
15 Jan
24 Feb
4 Feb
14 Feb
5 Jan

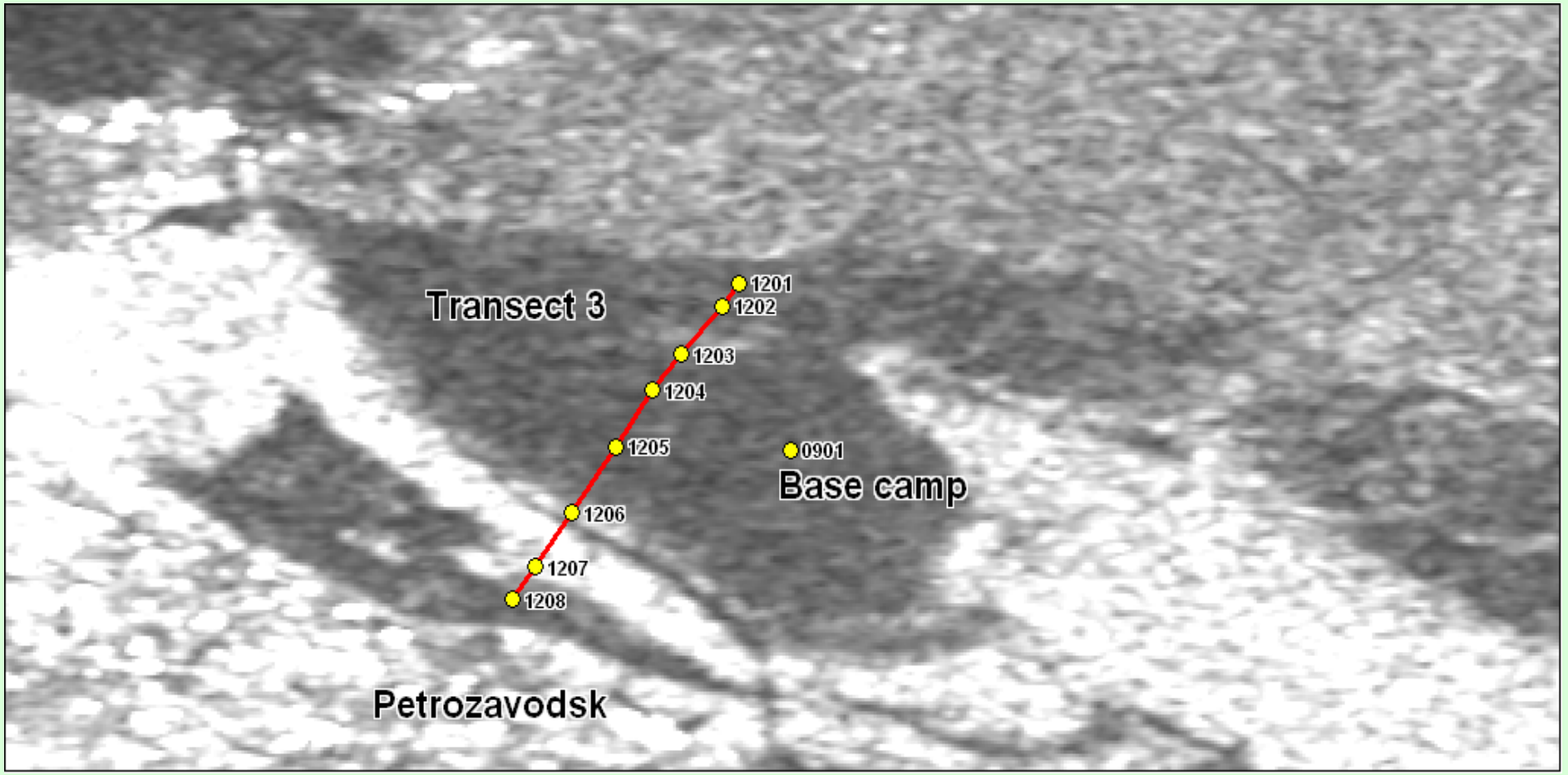

50
40
30
20
10
Backscatter (Ku, Ice, dB)
Young,
smooth ice
Mature ice
Open water
25 Jan
24 Feb
15 Jan
4 Feb
14 Feb
5 Mar
5 Jan
34.4
34.6
34.8
35
35.2
35.4
Lon (°E)

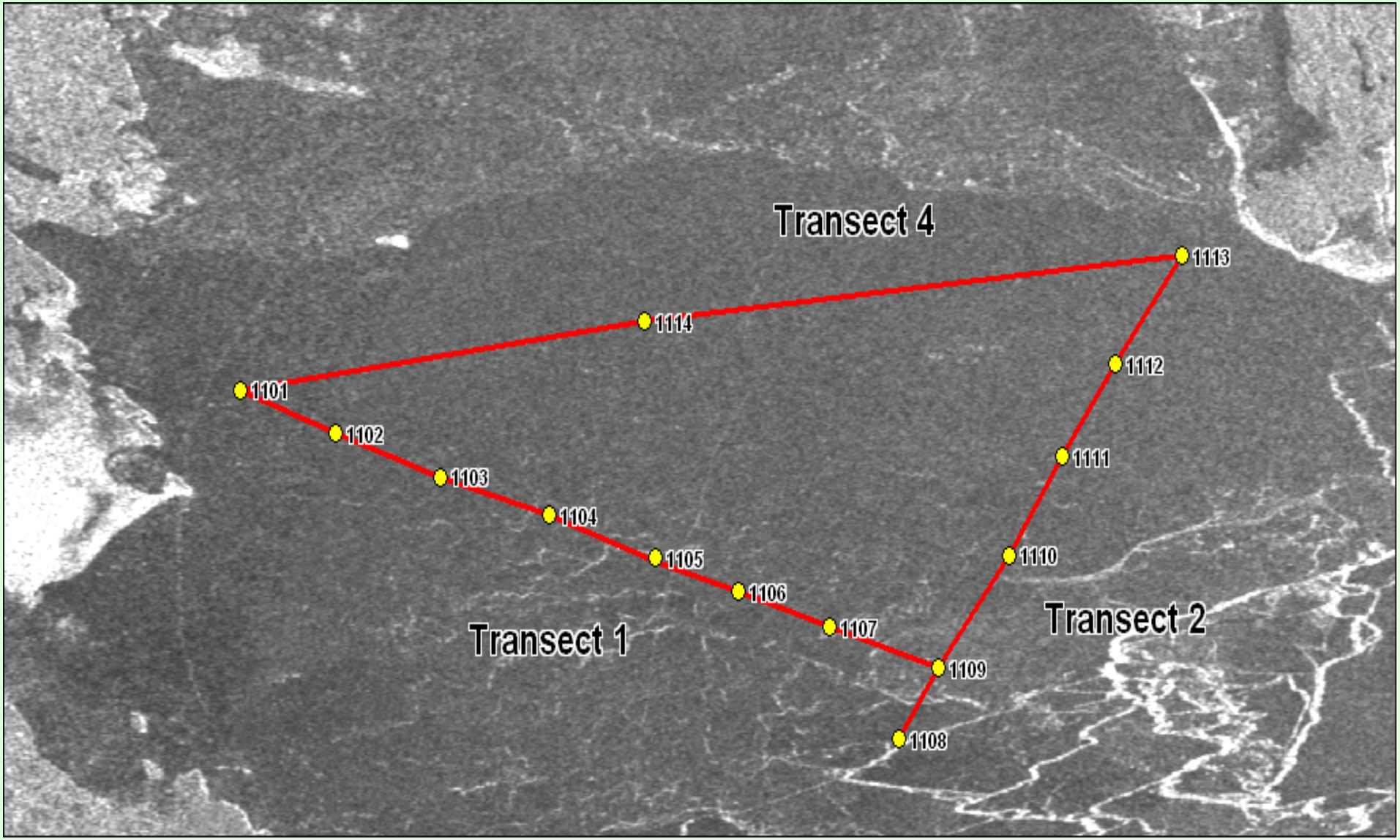

50
40
30
20
10
Backscatter (Ku, Ice, dB)
Young,
smooth ice
Mature ice
Open water
34.4
34.6
34.8
35
35.2
35.4
Lon (°E)
25 Jan
24 Feb
15 Mar
15 Jan
4 Feb
14 Feb
5 Mar
5 Jan


50
40
30
20
10
Backscatter (Ku, Ice, dB)
Young, smooth ice
Mature ice
Open water
34.4
34.6
34.8
35
35.2
35.4
Lon (°E)
25 Jan
25 Mar
15 Jan
15 Mar
5 Mar
24 Feb
4 Feb
14 Feb
5 Jan


50
40
30
20
10
Backscatter (Ku, Ice, dB)
Young,
smooth ice
Mature ice
Open water
34.4
34.6
34.8
35
35.2
35.4
Lon (°E)
25 Jan
25 Mar
15 Jan
15 Mar
4 Apr
5 Mar
24 Feb
4 Feb
14 Feb
5 Jan


50
40
30
20
10
Backscatter (Ku, Ice, dB)
Young, smooth ice
Mature ice
Open water
34.4
34.6
34.8
35
35.2
35.4
Lon (°E)
25 Jan
25 Mar
15 Jan
15 Mar
4 Apr
5 Mar
24 Feb
4 Feb
14 Feb
14 Apr
5 Jan


Transect 3
1201
1202
1203
1204
1205
1206
1207
1208
0901
Base camp
Petrozavodsk


Transect 4
1113
1114
1112
1101
1102
1111
1103
1104
1110
1105
1106
Transect 2
1107
Transect 1
1109
1108

THE LORD OF THE BAIKAL ICE RINGS

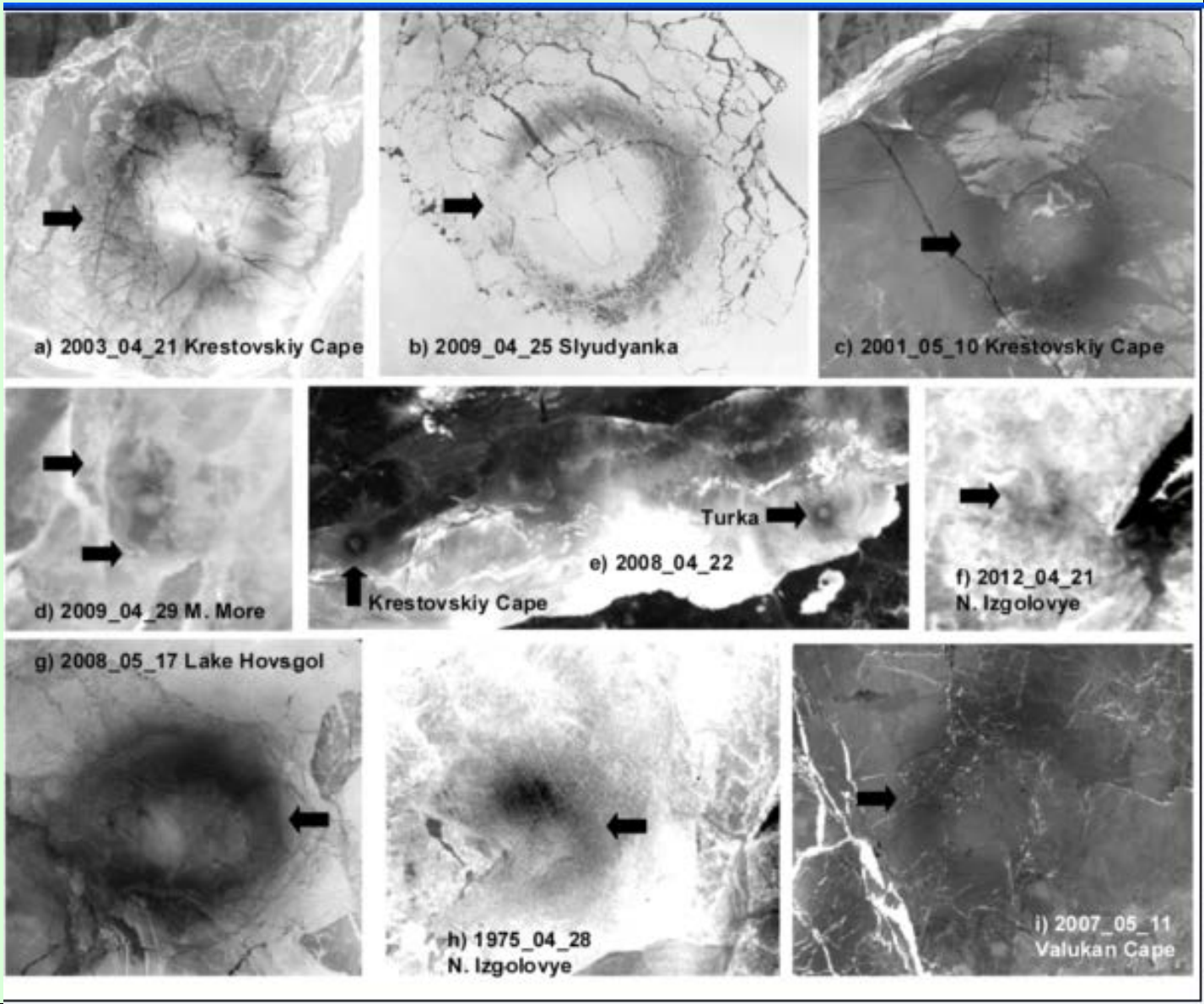
“Three Rings for the Elven-kings under the sky,
Seven for the Dwarf-lords in their halls of stone,
Nine for Mortal Men doomed to die,
One for the Dark Lord on his dark throne,
and many more rings – hidden in the dark and thin ice of the Lake Baikal…”
(J.R.R. Tolkien, updated)

Diameter 5-7 km. Circular shape
Ice is thinner in the ring

Ice rings

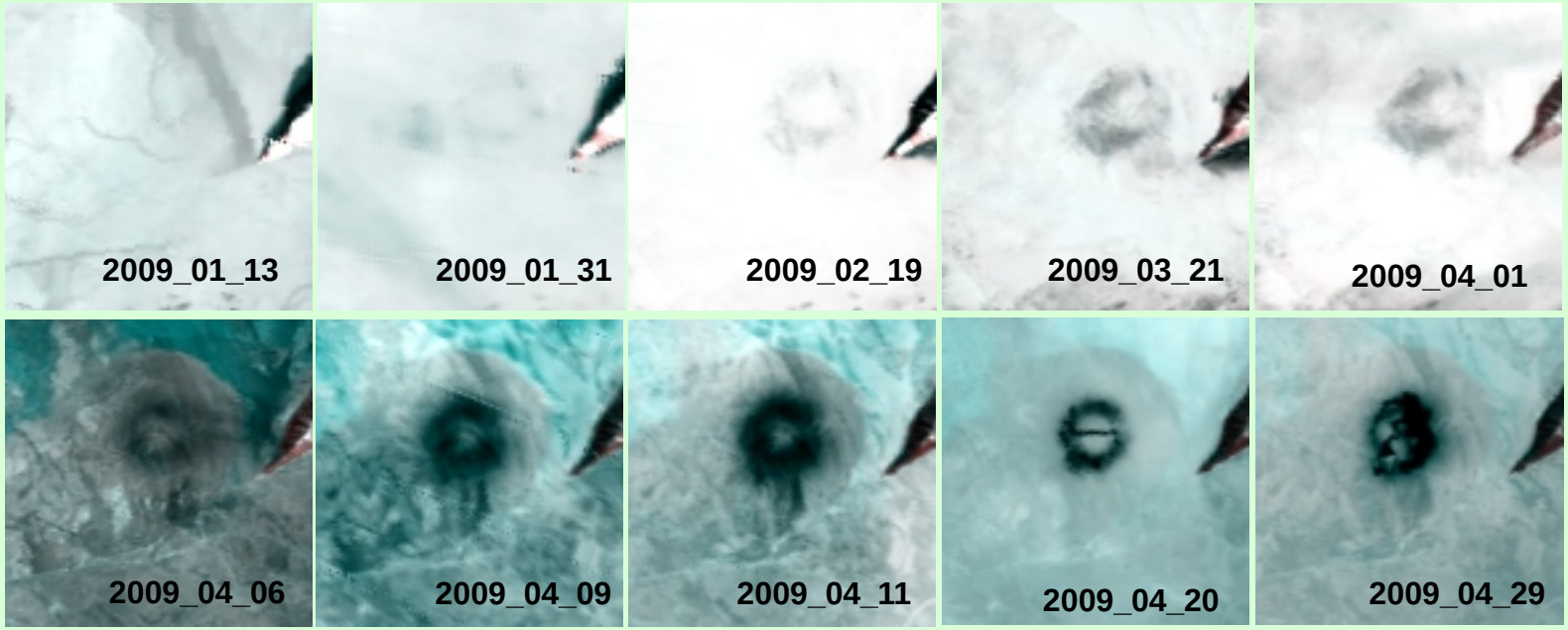
Different years

Different places

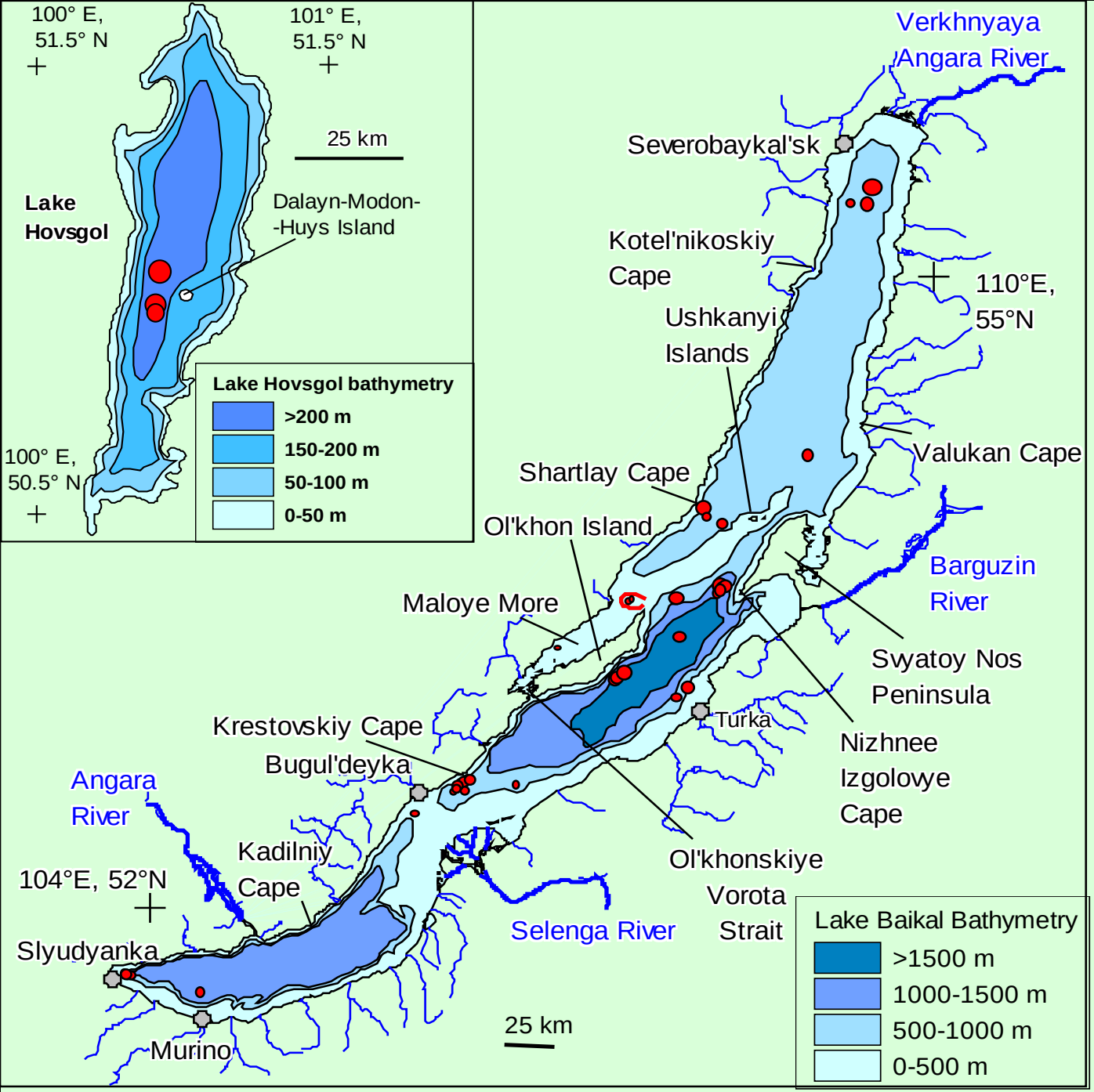


Landsat 1-7 (a, c, g-i), MODIS/Terra (d-f) and ISS (b) imagery.

Evolution



Cape Nizhneye Izgolovye (Middle Baikal), January-April 2009



Inventory

Baikal:
45 (13 known)

Hovsgol:
4 (0 known)

Winter	Name	Diameter, km	Lon E	Lat N	First seen[a]	Last seen[a]	Duration, days[b]	Depth, m	Form[c]
1974	Shartlay C.	8.2	108.25	53.90	03/01	03/01	(1)	850	R
1974	Kotel'nikovskiy C.	2.4	109.14	55.02	03/01	03/01	(1)	850	DR
1975	N. Izgolovye C.	5.4	108.36	53.50	04/28	04/28	(1)	1550	DR
1975	Hovsgol	2.5	100.40	50.97	05/19	05/20	(2)	>200	R
1977	Krestovskiy C.	3.6	106.42	52.55	05/06	05/06	(1)	1050	DR
1985	N. Izgolovye C.	7	108.42	53.52	04/29	05/06	(1)[d]	1450	OR
1994	N. Izgolovye C.	6	108.38	53.51	04/10	04/16	(7)	1450	OR
1999	Krestovskiy C.	6.4	106.42	52.60	04/18	04/18	(1)	900	R
2000	Slyudyanka	5.6	103.83	51.68	04/27	04/27	(1)	750	R
2000	Severobaykalsk	5.4	109.37	55.35	05/15	05/15	(1)	750	R
2001	Krestovskiy C.	4.4	106.34	52.55	04/21	05/10	(20)	850	DR
2002	M. More North	7.6	107.70	53.46	04/19	04/26	(8)	400	E
2002	M. More South	3.4	107.14	53.24	04/19	04/26	(8)	60	R
2002	Olkhon East	7.6	107.58	53.09	04/26	04/26	(1)	1550	R
2003	Krestovskiy C.	5.2	106.45	52.60	04/03(4)	04/28(4)	26	950	R
2003	Off Krestovskiy C.	4.4	106.81	52.58	04/17(7)	05/08(1)	22	950	R
2003	Hovsgol	2.9	100.42	51.04	06/13	06/13	(1)	>200	R
2004	Krestovskiy C.	6	106.42	52.59	04/21(5)	05/02(3)	12	900	R
2005	Krestovskiy C.	5.6	106.45	52.61	04/15(1)	05/01(3)	17	900	R
2005	M. More North	4.6	107.68	53.46	05/01(3)	05/13(2)	13	370	R,H
2005	Olkhon East	7	108.07	53.29	05/13(5)	05/23(1)	11	1550	OR
2005	Ushkanyi Islands	6.4	108.40	53.83	05/21(4)	05/23(4)	3	650	R
2007	Murino	6	104.40	51.60	04/11(2)	04/24(2)	14	1150	R
2007	Valukan C.	5.4	109.01	54.16	05/11(5)	05/16(1)	6	770	R
2008	Hovsgol	2.2	100.40	50.95	05/17	06/02	17	>200	OR
2008	Turka	4.6	108.04	53.00	04/15(5)	04/22(11)	8	670	R
2008	Krestovskiy C.	5.4	106.39	52.59	04/10(2)	04/23(10)	14	850	R
2008	Slyudyanka	4.4	103.81	51.69	04/16(1)	04/30(3)	15	650	R
2009	N. Izgolovye C.	6.6	108.37	53.53	02/01(5)	05/03(1)	92	1350	R
2009	Slyudyanka	5.2	103.88	51.67	04/04(3)	04/27(2)	24	1050	R
2009	M. More North	3.8	107.70	53.47	04/04(3)	05/04(2)	31	370	R,H
2009	Turka	7.6	108.13	53.05	04/09(2)	04/29(4)	21	500	R,H
2010	Severobaykalsk N	7.6	109.55	55.42	01/31(9)	04/27(2)	87	750	R
2010	Severobaykalsk S	6	109.50	55.34	01/02(0)	05/07(4)	126	750	R
2010	Krestovskiy	4.6	106.35	52.57	04/21(2)	05/11(6)	21	950	R,H
2010	Bugul'deyka	4.8	106.04	52.45	04/21(2)	05/16(1)	26	450	R,H
2011	N. Izgolovye C.	8	108.38	53.53	04/15(2)	05/02(3)	18	1150	R
2011	Olkhon East	8	107.64	53.12	04/13(3)	04/26(5)	14	1350	R
2011	Krestovskiy C.	6.2	106.36	52.57	03/31(4)	04/27(4)	28	850	R
2012	N. Izgolovye C.	6	108.39	53.52	04/06(3)	04/28(1)	23	1450	R
2012	Olkhon East	7.6	107.59	53.09	04/06(11)	04/21(3)	16	1550	R
2012	Krestovskiy C.	6.8	106.37	52.58	04/06(7)	04/21(3)	16	850	R
2013	Krestovskiy C.	4.8	106.36	52.56	04/18(2)	05/04(2)	17	900	R,H
2013	Sv. Nos - Olkhon	7.6	108.04	53.47	04/29(5)	05/13(2)	15	750	R
2013	Shartlay C.	5.4	108.27	53.85	05/07(3)	05/19(2)	13	850	OR
2014	Krestovskiy C.	6	106.47	52.61	04/17(1)	04/22(4)	9	850	DR
2014	N. Izgolovye C.	7	108.38	53.50	04/01(2)	04/23(3)	23	1450	R
2015	Valukan C.	5.6	109.18	54.13	05/08(1)	05/10(3)	3	650	OR
2015	Hovsgol	6.2	100.45	51.03	05/20	05/29	(10)	>200	OR

Inventory of ice rings and their characteristics

Inventory

The most complete inventory

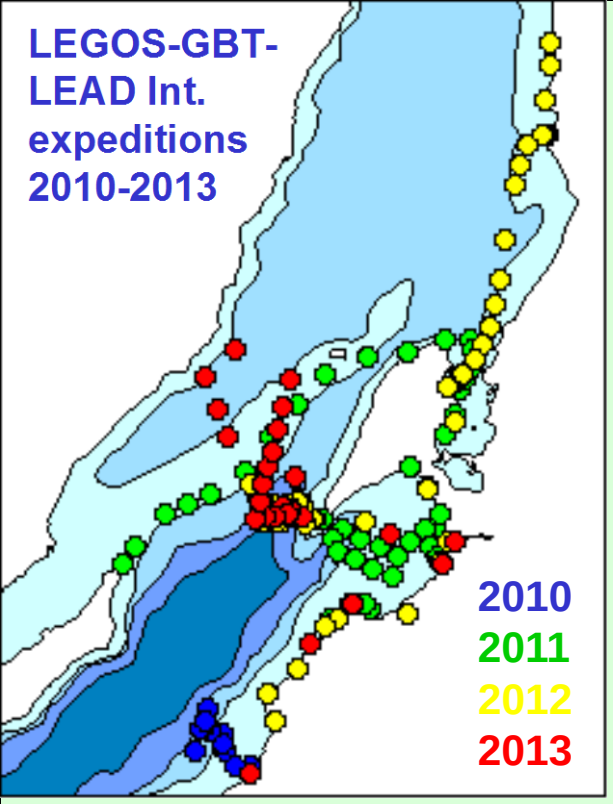
Not a new phenomenon (1970ies)

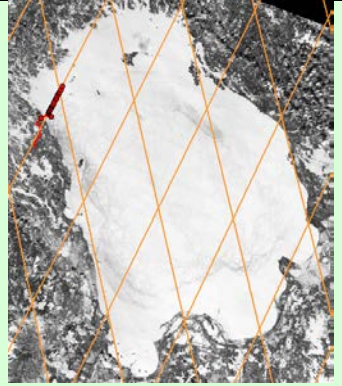
Rings with small depths - no gas release origins

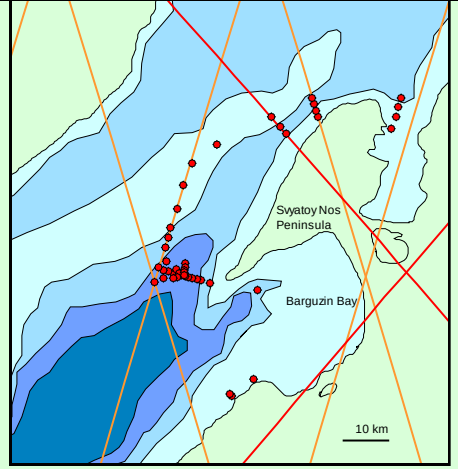
Duration 5-10 days (1-126 days)

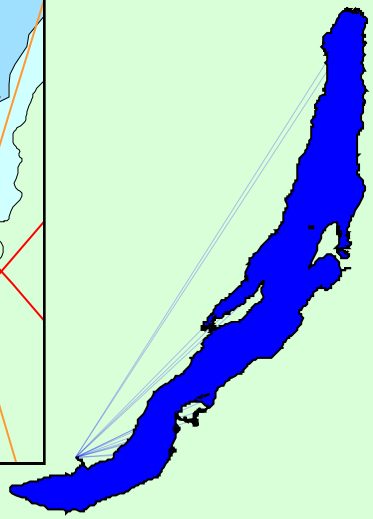
Most frequently - April (Jan-May)

N. Izgolovye and Krestovskiy Capes

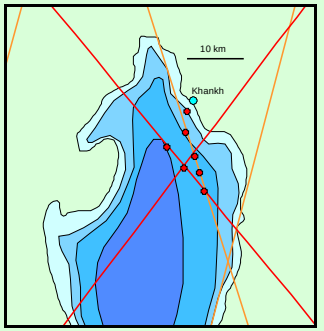




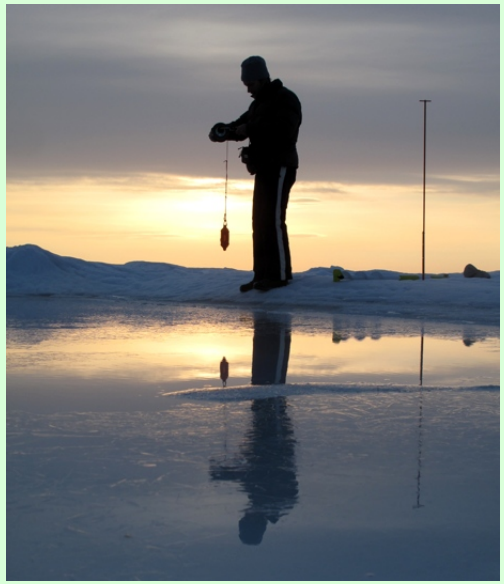




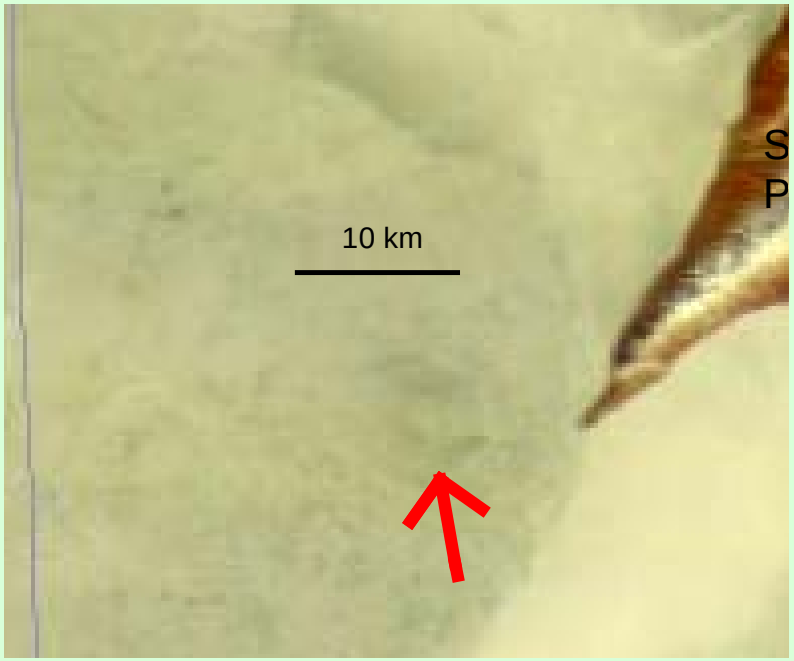
Coop: Khovsgol Nat.Parc

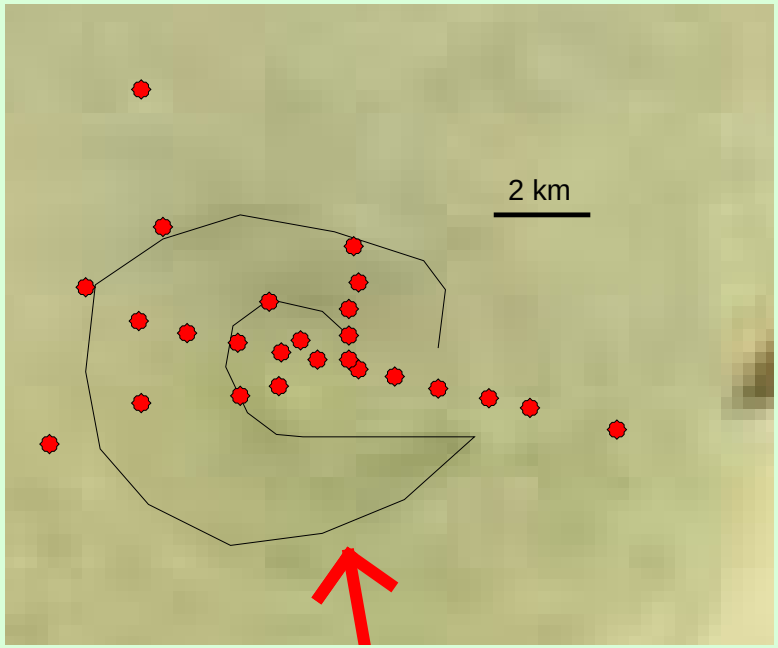


From ringspotting to ring hunting



Detailed survey of the giant ice ring

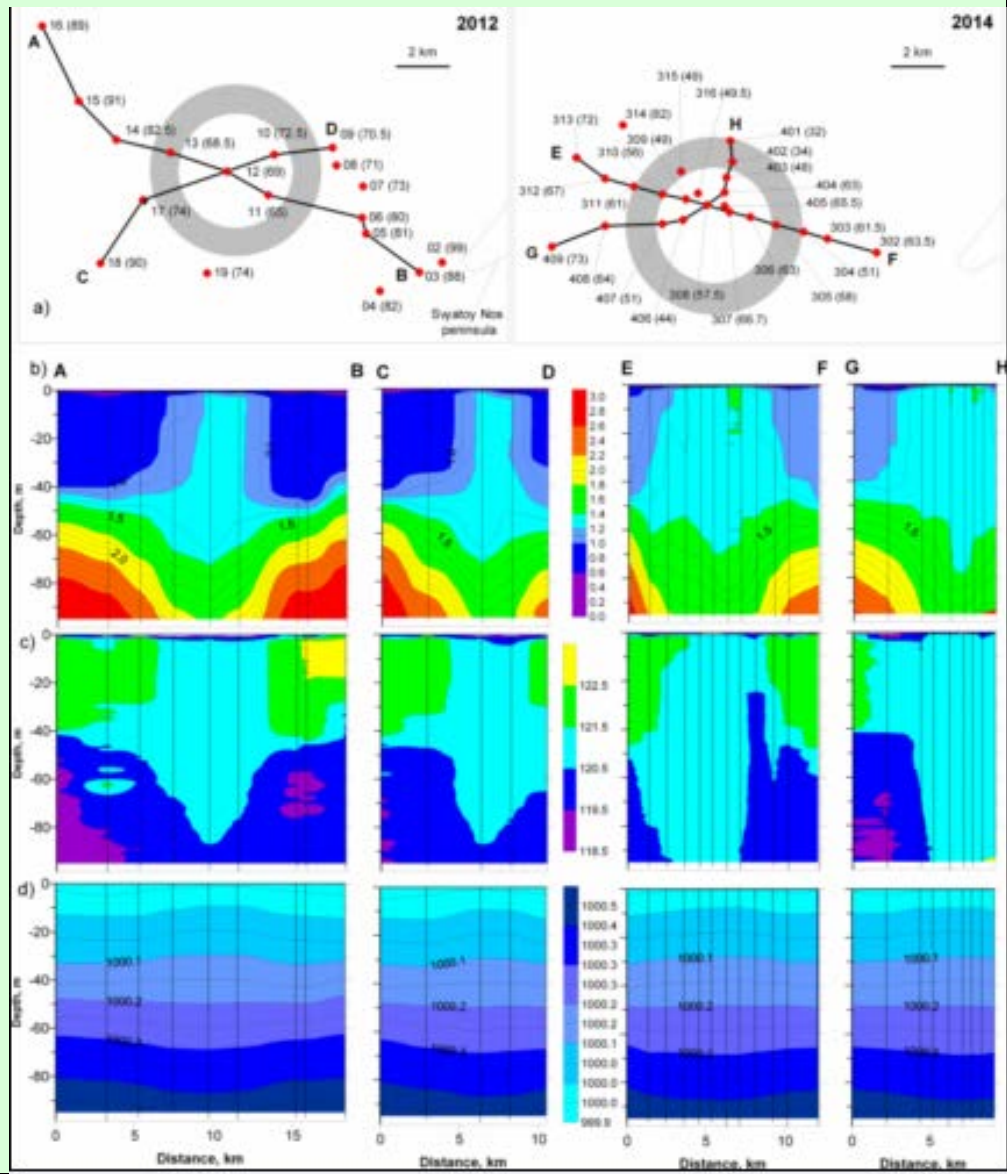




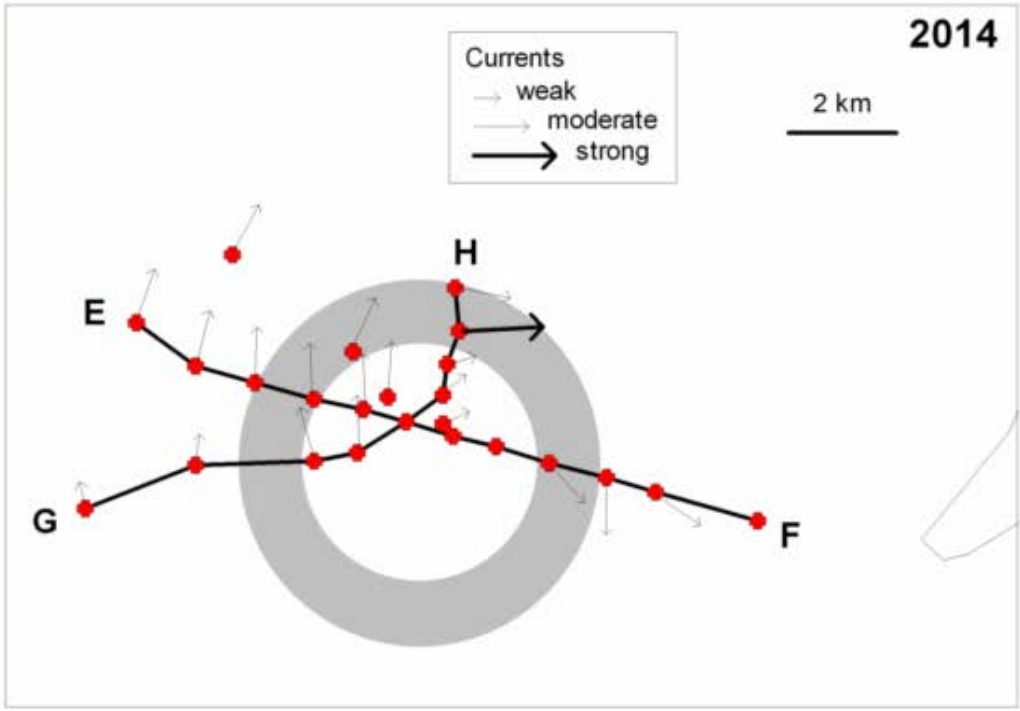
Anomalous water structure

- Anticyclonic lens-like eddy
- Exist before and during ice ring appearance
- Ring radius is comparable to Rossby radius
- Clockwise currents
- Increased melting at eddy boundary
- Ice rings - surface manifestation of eddies
- Eddy origin - combination of coastal currents, bathymetry, wind forcing, seiches, river input etc
- Eddy formation - during ice cover presence or before ice formation?
- Need for dedicated studies

Nizhneye Izgolovye



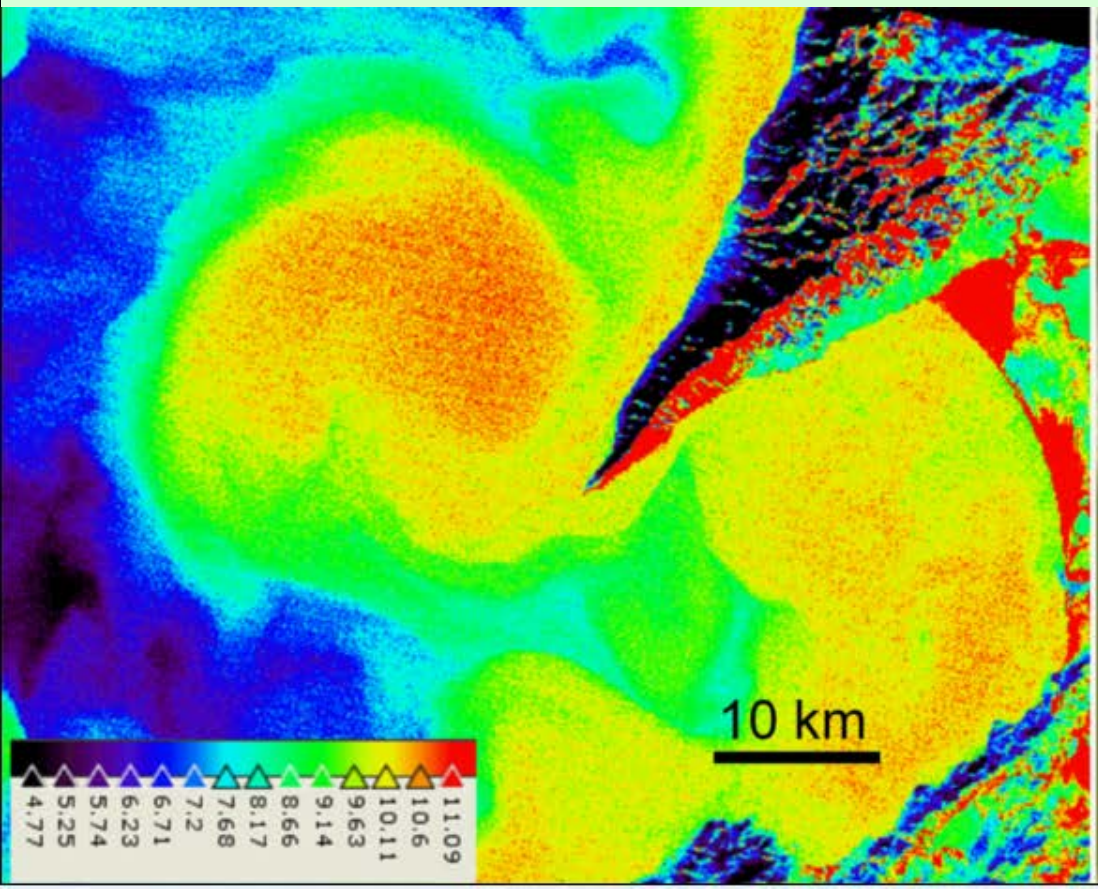
Ice structure and currents

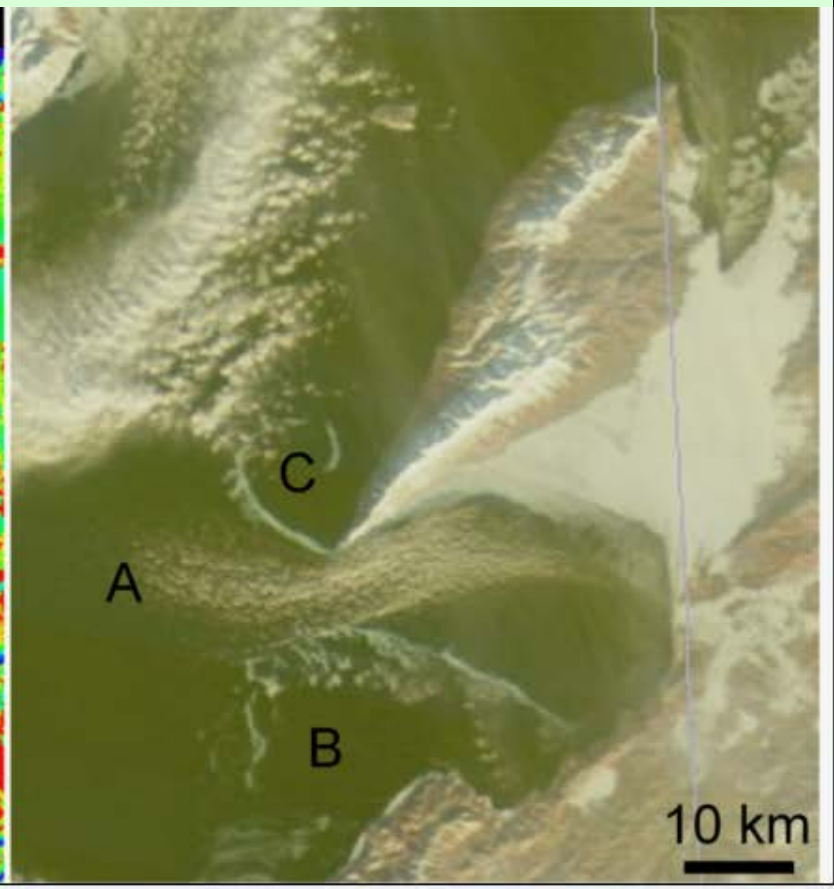


Crystals size - 10-12 cm long, 2-3 cm thick), 3 April 2014

Currents 3-4 April 2014

Water dynamics



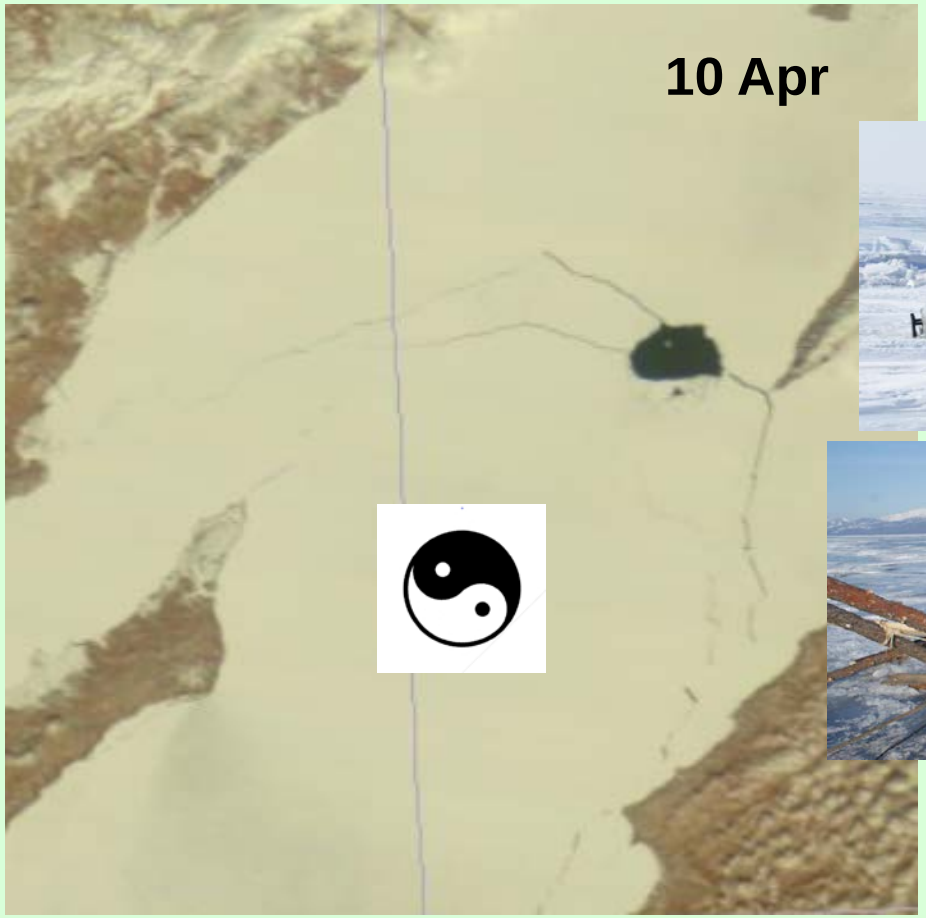


Landsat TIR 26 September 2002
-anticyclonic warm eddy.

MODIS 31 December 2011

Kouraev et al., Limnology and Oceanography, 2016

Ice ring 2016



UAZ trapped in ice and rescue activities, March 2016
(c) A. Beketov

Field work 2016