Lake and river ice cover
Frozen wetlands

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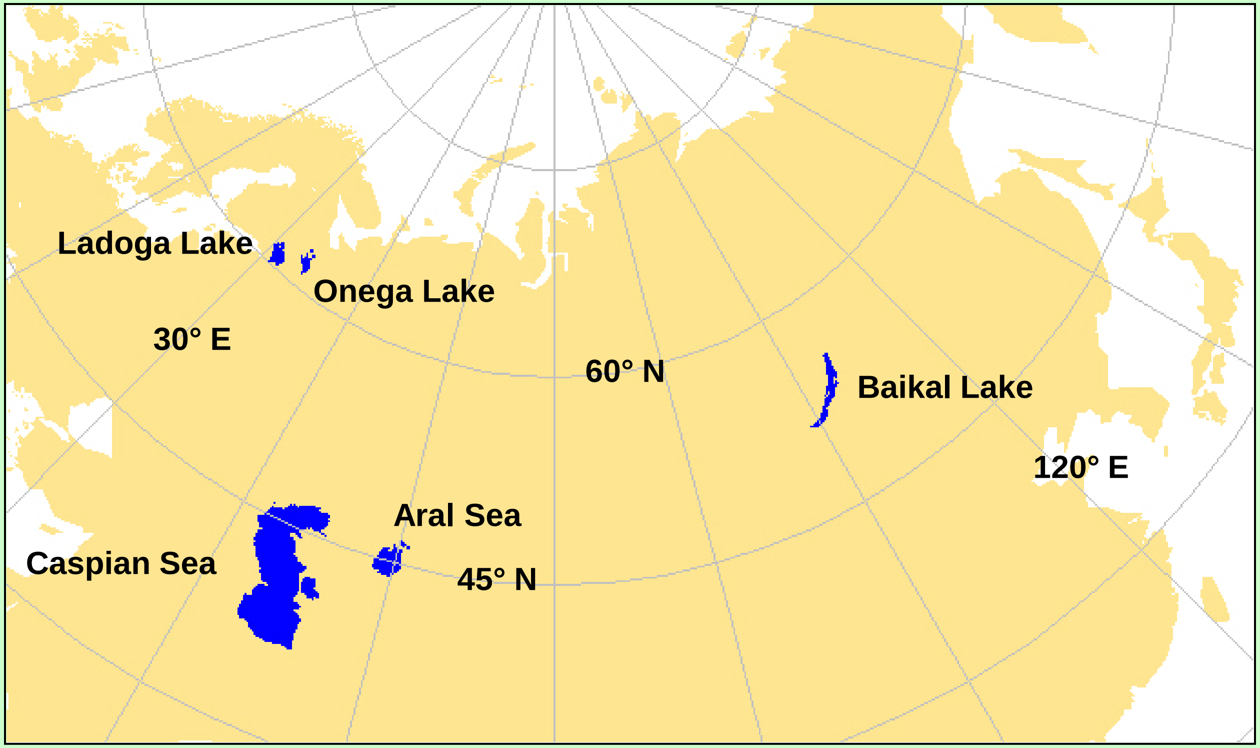
STUDY AREAS



Five largest Eurasian water bodies

Salt / fresh water

Seasonal ice cover - forming every year

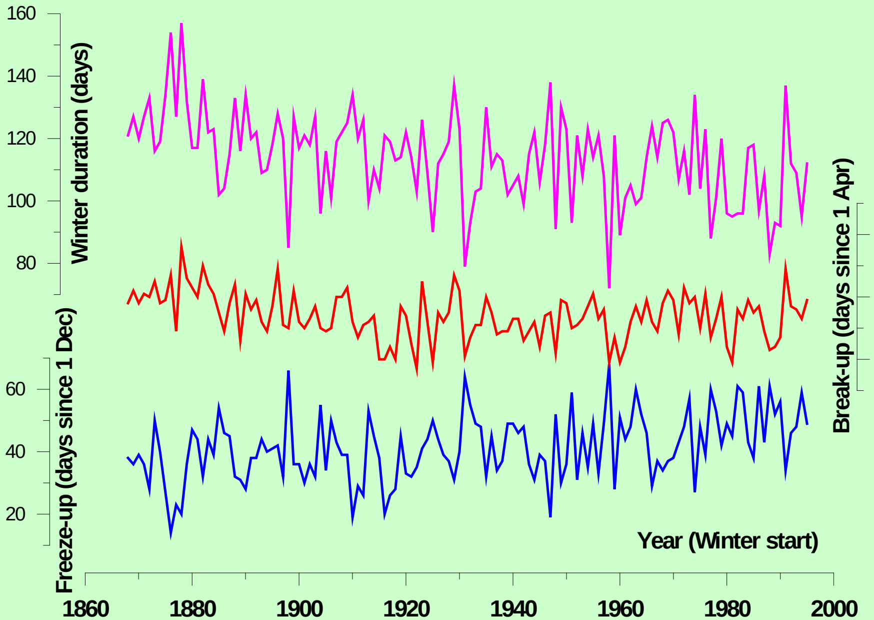
Full / partial ice coverage depending on winter severity

	Surface, km2	Volume, km3	Max depth, m	Mean depth, m	Comment
Caspian Sea	371000	78200	1025	211	World's largest inland water body
Baikal Lake	31500	23600	1637	749	Deepest lake in the world, 2nd largest in Eu
Ladoga Lake	18130	908	230	50	4th largest in Eurasia
Onega Lake	9891	280	120	28	5th largest in Eurasia
Aral Sea 1960	67000	1083	63	16	
Aral Sea 2004	16000	100	40	6	

Ice and snow for people and nature

Good indicator of large-scale climate change

Formation of hydrophysical fields



Baikal ice phenology and winter duration - Listvyanka station (since 1868)

Influence on spring bloom of diatoms and primary production

Living conditions for endemic animals


Fishermen, Barguzin bay, 2013

Practical aspects - transport on ice, fishing, tourism

Opening of ice route to Ol'khon island, 11 February, 2004


Tourists on Baikal ice

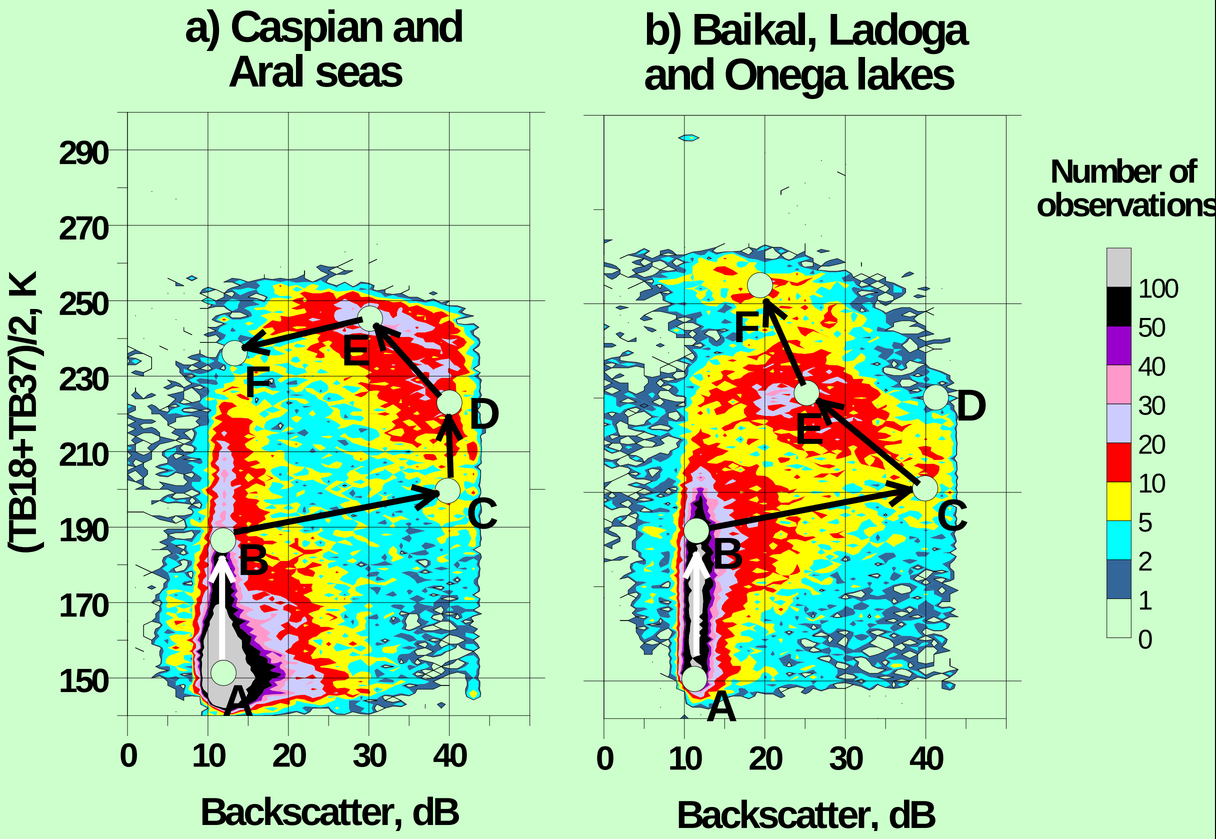
(Photo by Andrei Suknev)

Combination of simultaneous active (altimeter) and passive (radiometer) microwave data

Altimetry method

Ice / water discrimination methodology: developed, validated and tested for seas and lakes

Kouraev et al.,
2003 Polar Research
2004 JMS
2004 IEEE TGRS
2007 RSE
2007 L&O
2008 SiG

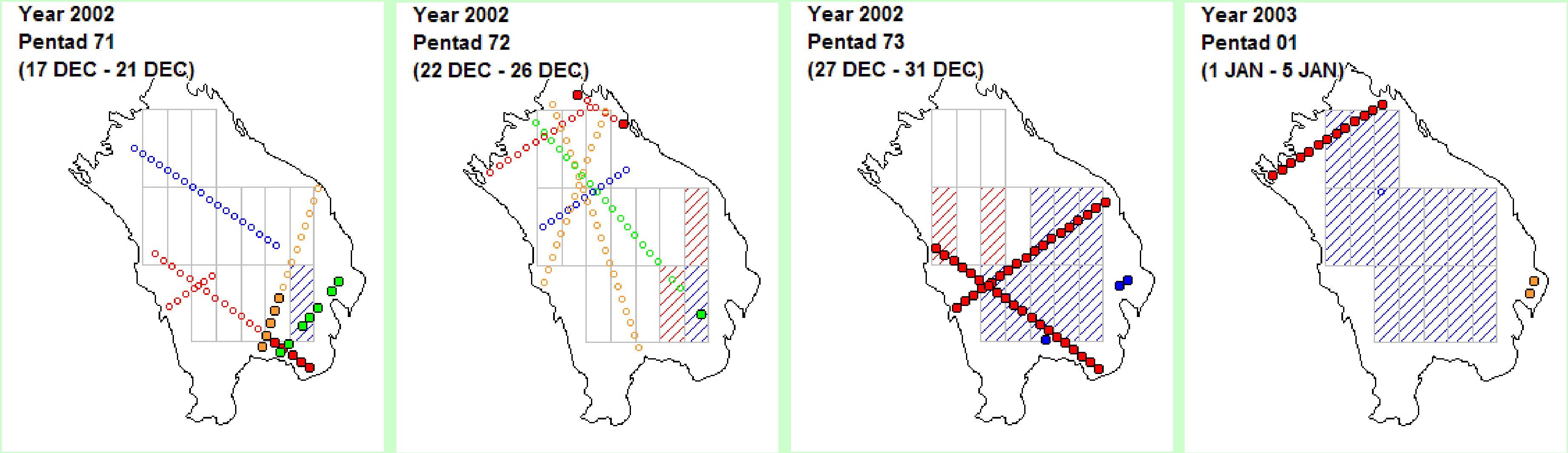


Schematic representation of the temporal evolution of T/P observations in the space of backscatter vs. TB/2. Schema is overlaid on two-dimensional histograms (total summed values) for Caspian and Aral seas (a) and Baikal, Ladoga and Onega Lakes (b)

Combining benefits of the two platforms

Mapping approach

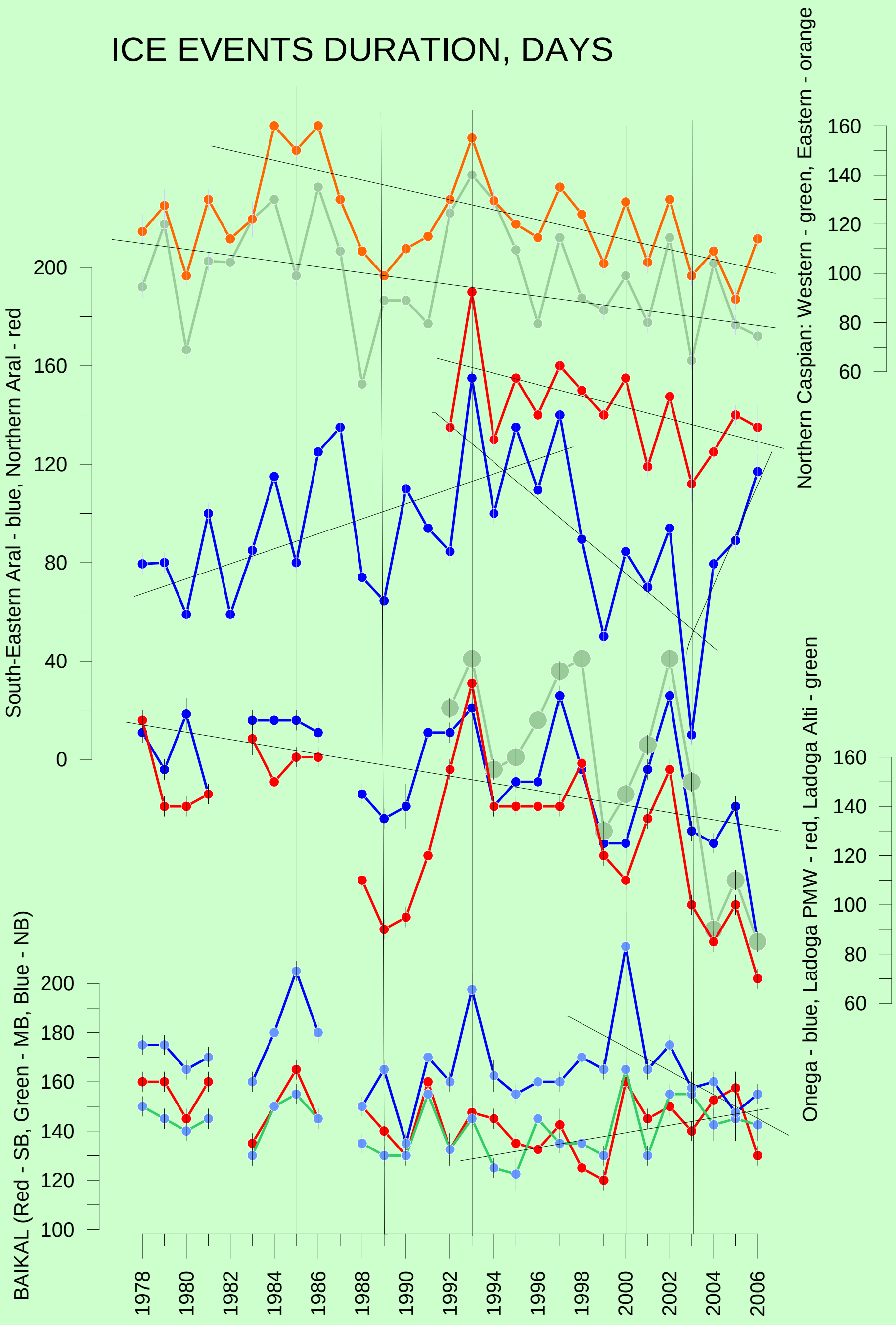
Working at 5 days resolution (pentads)



Freezing of the Ladoga Lake - a sequence of four pentads during winter 2002/03

SSM/I - wide spatial coverage, high temporal resolution
Altimetry - high radiometric and along-track spatial resolution

Resulting time series of ice events



Shorter winters - but not everywhere!

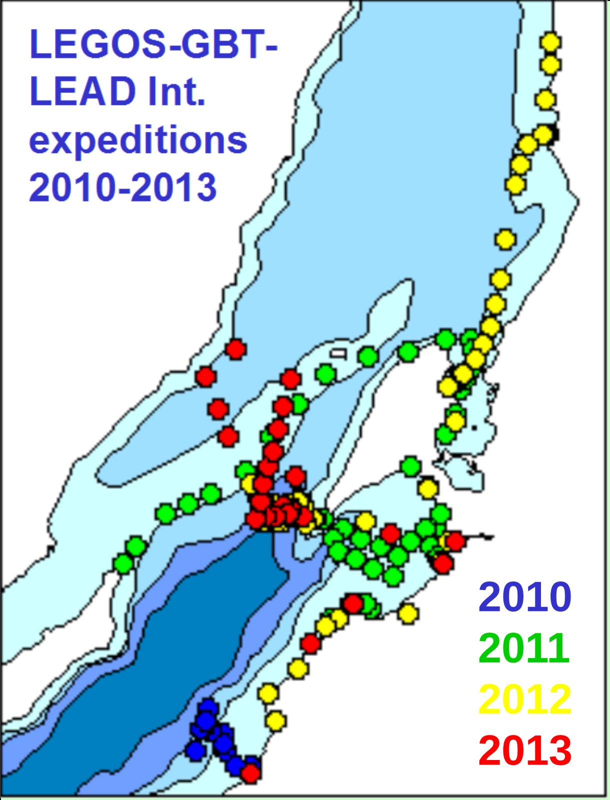
Caspian sea - constant gradual warming

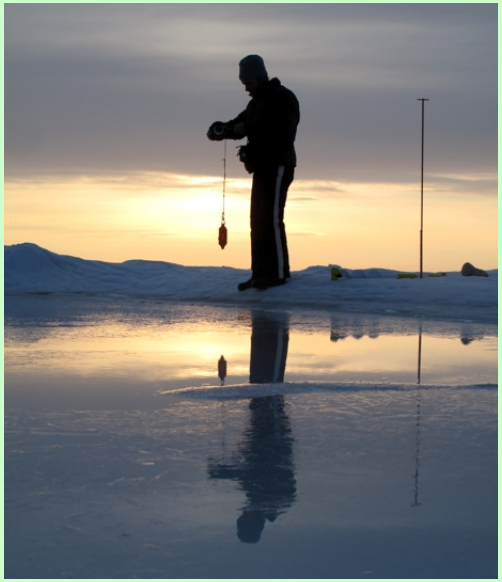
Aral sea - cooling followed by warming

Ladoga and Onega - very similar, recent warming

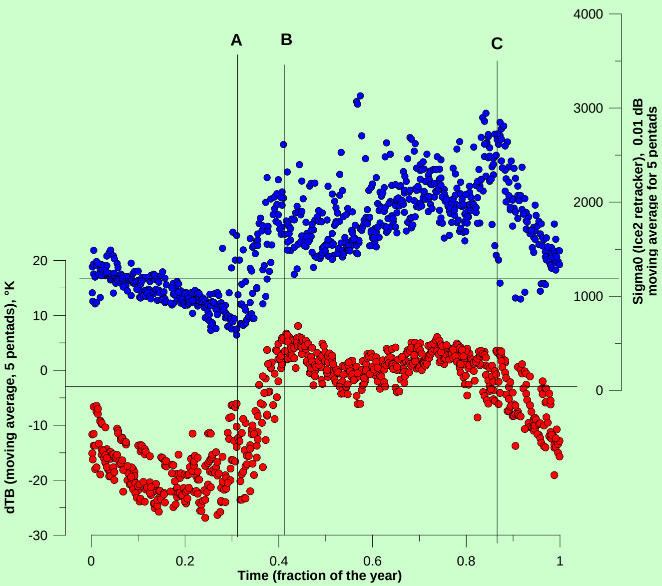
Baikal - warming in the north, but cooling in the center and south

Some winters are typical (cold 1993/94) but mostly regional character



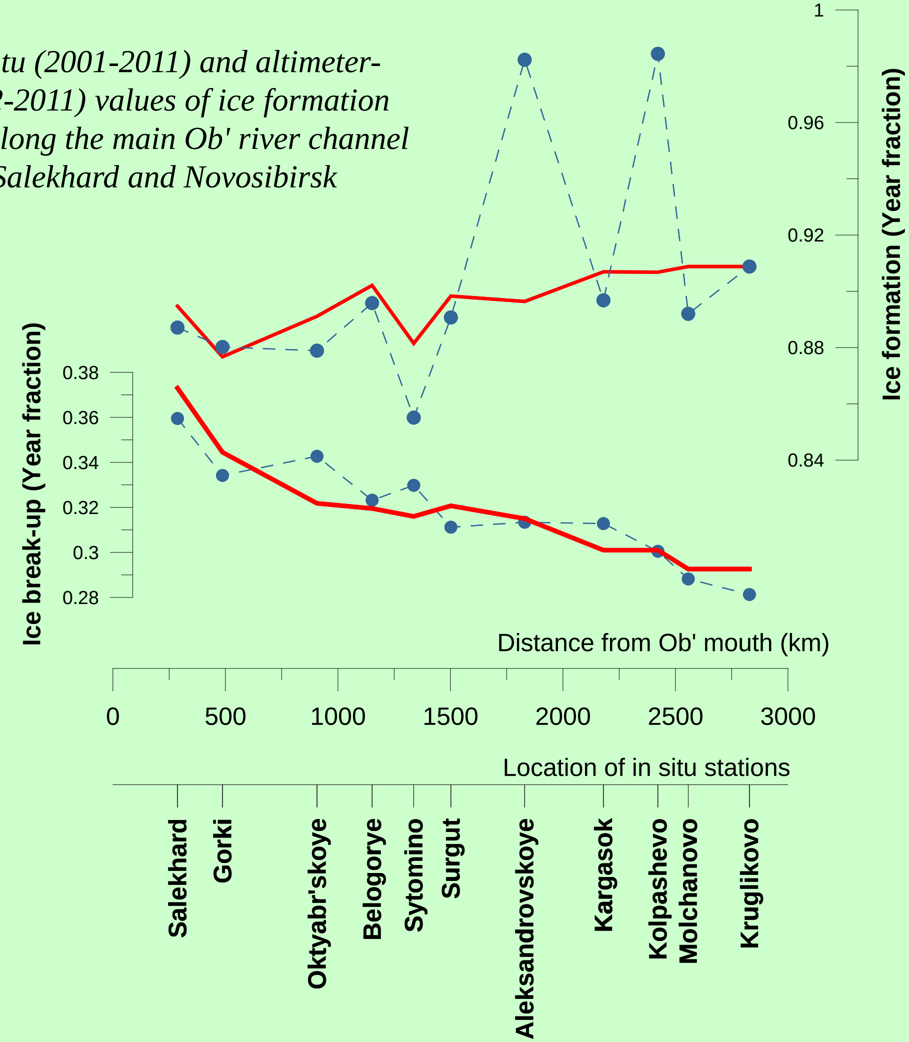


CNES TOSCA, ANR CLASSIQUE,
FP7 Monarch-A, CNRS PICS BaLaLaICA



Temporal (seasonal) variability of ENVISAT backscatter (Ice2 retracker) and dTB (TB365-TB238) values (moving average) for virtual stations in the Zone 1 (Salekhard)

Average in situ (2001-2011) and altimeter-derived (2002-2011) values of ice formation and break-up along the main Ob' river channel between Salekhard and Novosibirsk



96 ENVISAT virtual stations (2002-2011)

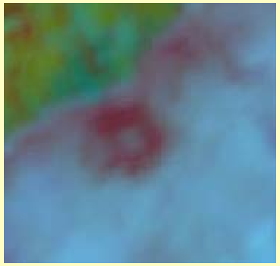
Timing: 6 dates
First ice / Ice with polynyas / Ice 100%
Ice with polynyas / Beginning of ice break-up / Open water

THE LORD OF THE BAIKAL ICE RINGS

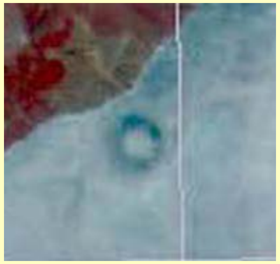
"Three Rings for the Elven-kings under the sky,
Seven for the Dwarf-lords in their halls of stone,
Nine for Mortal Men doomed to die,
One for the Dark Lord on his dark throne,
and many more rings - hidden in the dark and thin ice of the Lake Baikal…"
(J.R.R. Tolkien, updated)

Baikal Ice Rings

Krestovskiy Cape



1999 04 18



2003 04 20

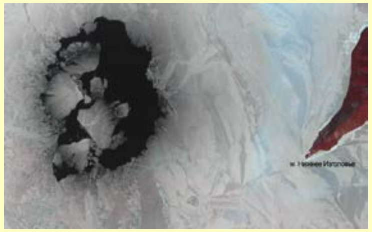
2005 04 24

2008 04 22

Radius about 2.3 - 2.9 km

Nizhnee Izgolovye Cape

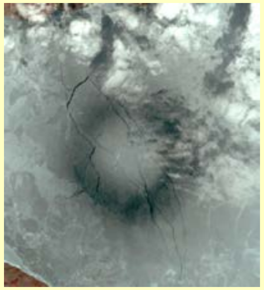
2009 04 15



2009 04 24

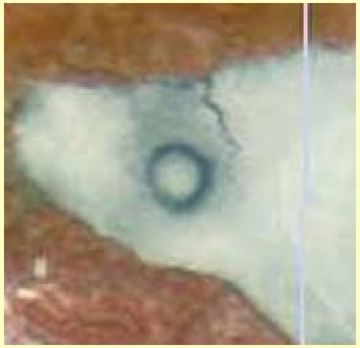
Radius about 2.8 km

Southern Baikal



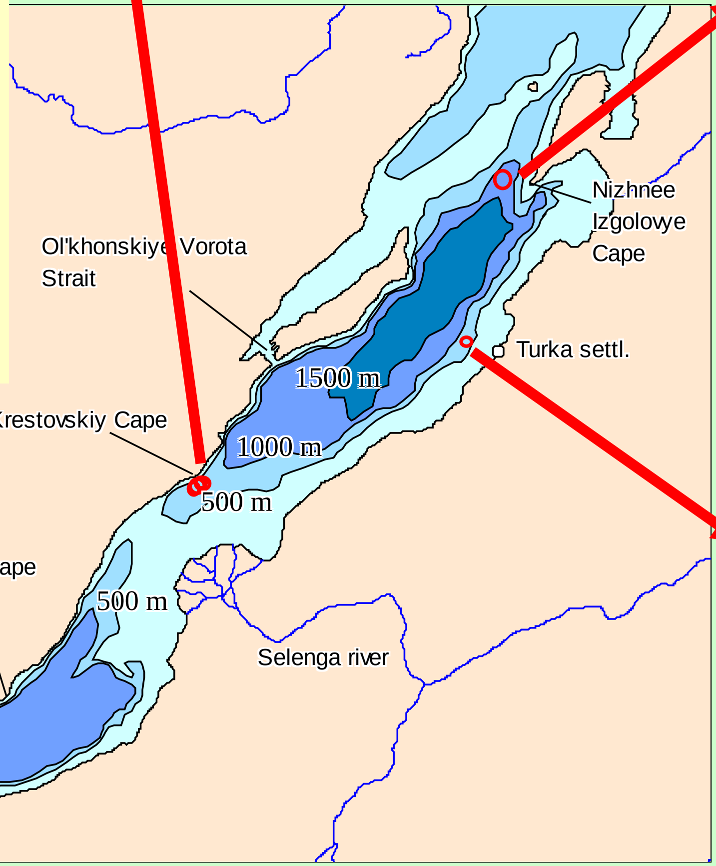
2009 04 20 SPOT

2009 04 25 ISS

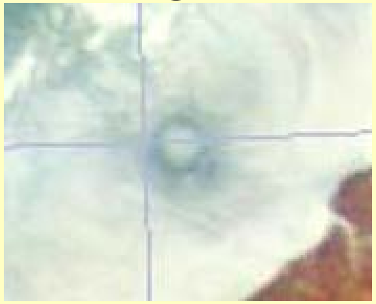


2009 04 24

Radius about 2.1 km



Turka region



2008 04 22

Radius about 1.9 km

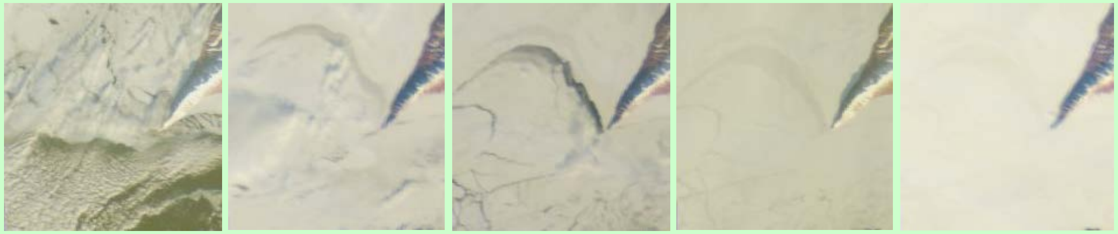
Rings are usually seen in April (no snow). But they could be formed earlier!

Formation time/duration

By 15 January ice cover was stable

By 1 February the ring can already be guessed through snow

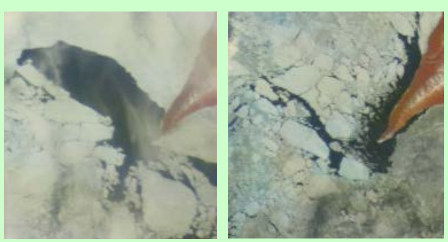
19-20 April - central part is broken in two



04 01 2009 | 08 01 2009 | 10 01 2009 | 13 01 2009 | 15 01 2009

31 01 2009 | 01 02 2009 | 02 02 2009 | 15 02 2009 | 19 02 2009 | 01 03 2009 | 12 03 2009 | 28 03 2009

04 04 2009 | 06 04 2009 | 09 04 2009 | 20 04 2009 | 24 04 2009 | 27 04 2009 | 29 04 2009 | 03 05 2009



04 05 2009 | 06 05 2009

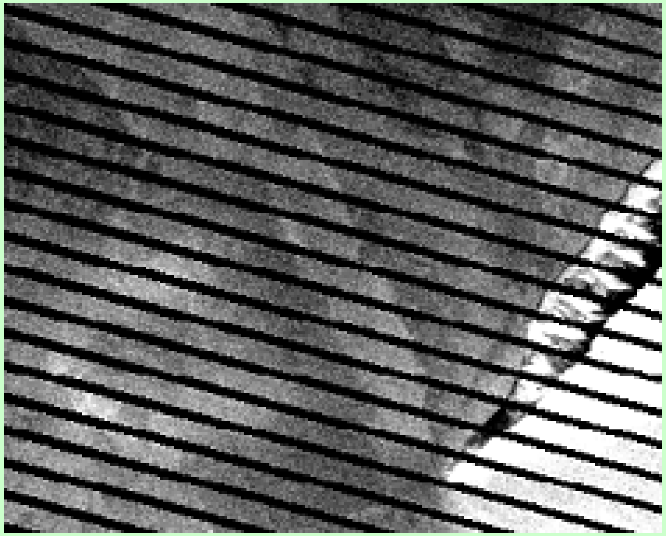
This ring has been formed between 15 January and 1 February 2009

Real timing of rings formation - ?

How much time is needed to form (sustain?) a ring?

Nizhnee Izgolovye Cape - Landsat ETM+

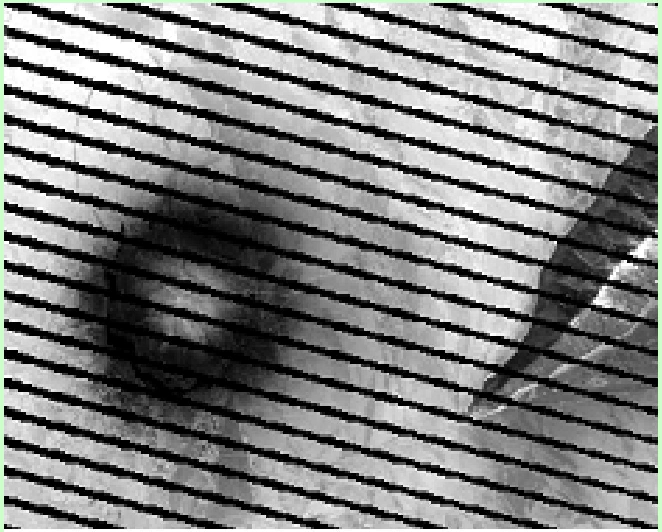
Near infrared (Band 40) **Thermal infrared (Band 62)**

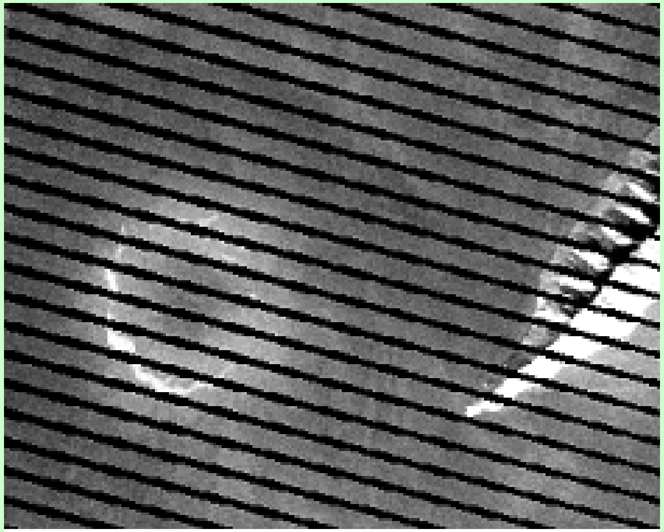


30 March 2009

Center/outside:
-5.6 .. -6.8°C

Ring: -4.9.. -5.7°C





15 April 2009

Center/outside:
-2 .. -2.4°C

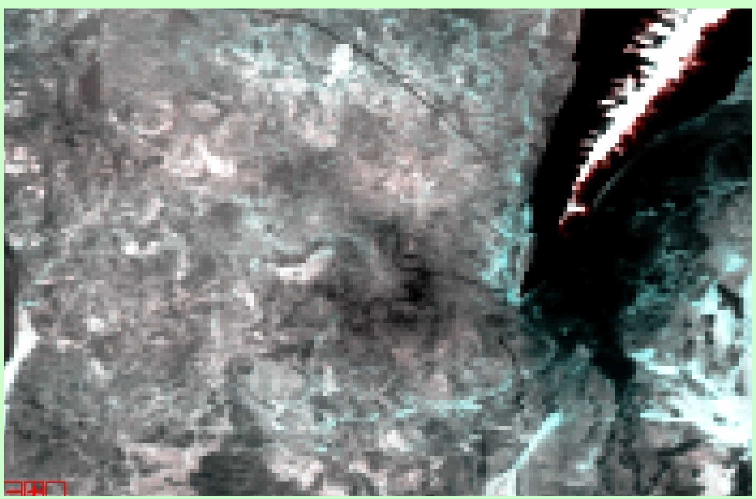
Ring: +0.74.. --1.35°C

Ring is 1°C warmer

Ice ring in 2012

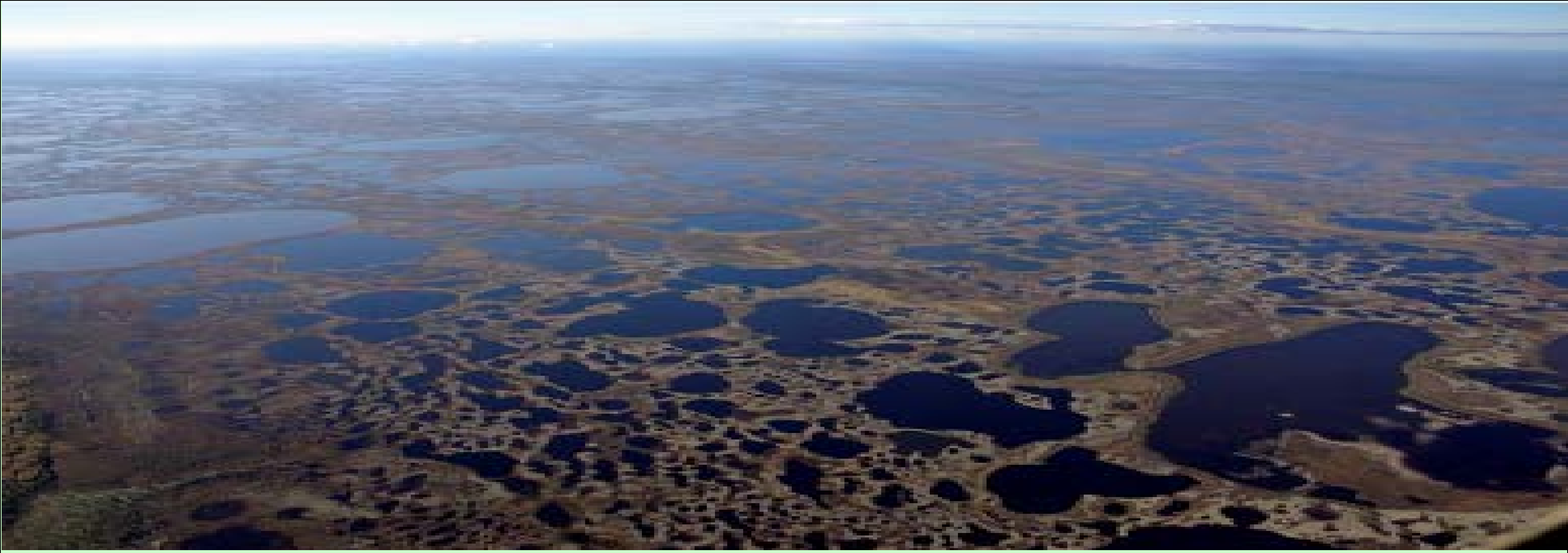
CTD casts, 5-7 April 2012

Seal's breathing hole: above and below



Gotcha! MODIS 21 April 2012

Wetlands

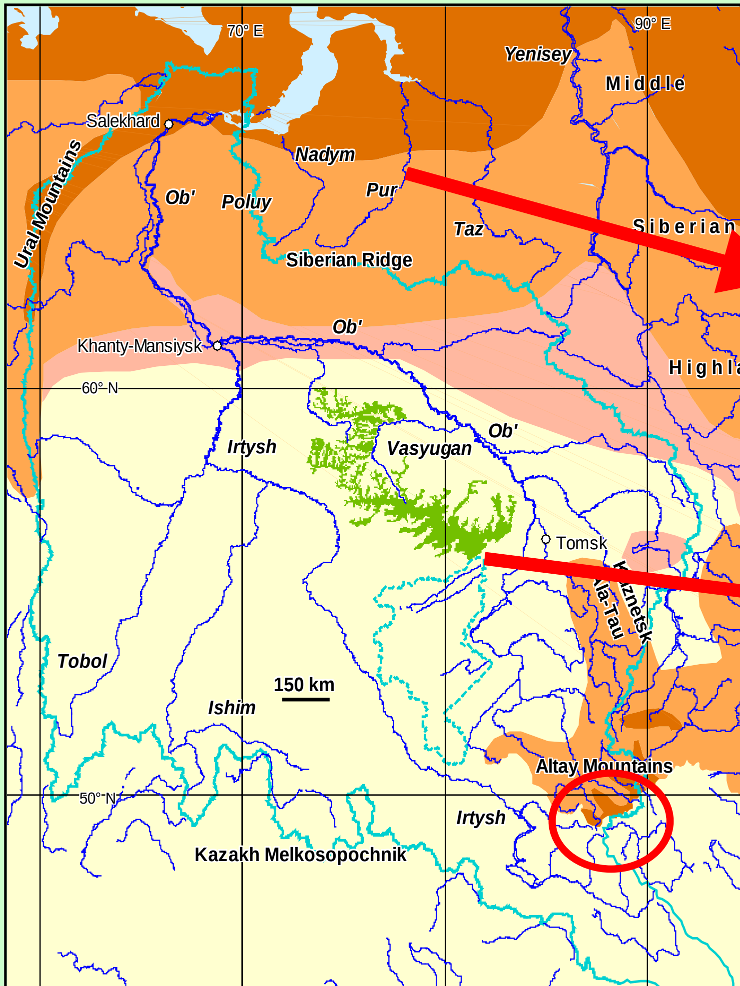


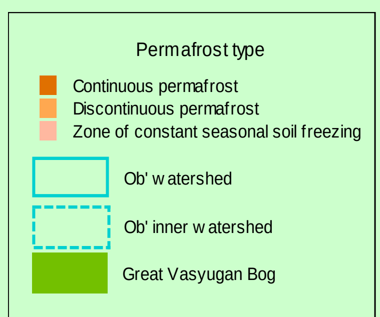
Western Siberian wetlands



Western Siberia: an unique region

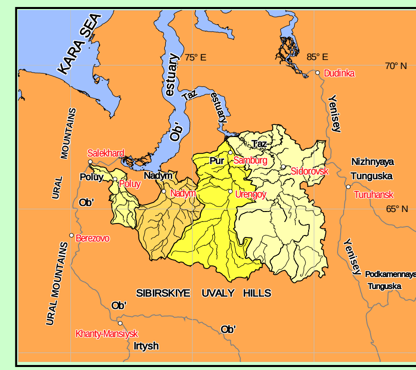
Ob' + Yenisey+ PNPT : 1250 km3 /year (greatest input among all other Arctic seas)





Flat relief - multitude of natural objects (large and small rivers and streams, extensive floodplains, lakes, mires, etc).

Poluy, Nadym, Pur and Taz (PNPT)



Homogeneous conditions, good climate indicator

Vasyugan bog

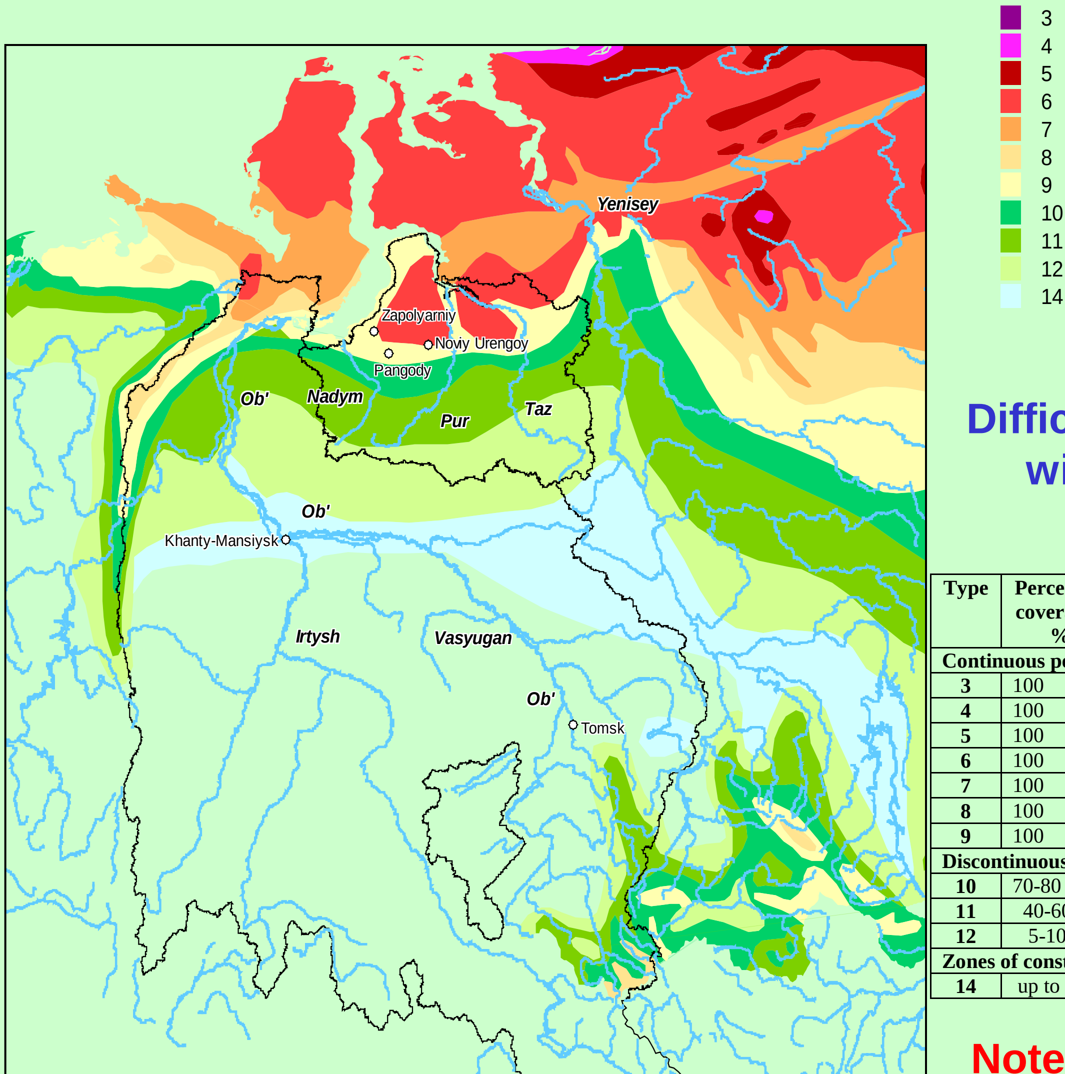
World's largest peatland (6.78 million ha). Appeared 10 000 years ago and constantly growing. 75% of the actual surface appeared during the last 500 years.

Influence of permafrost. Active layer depth in tundra 20-25 cm N to 80-90 cm S, taiga - up to 2m.

Permafrost conditions

Carbon cycle

Permafrost types of Russian Federation
(after K.A.Kondratyev and V.A.Kudryavtsev classification)

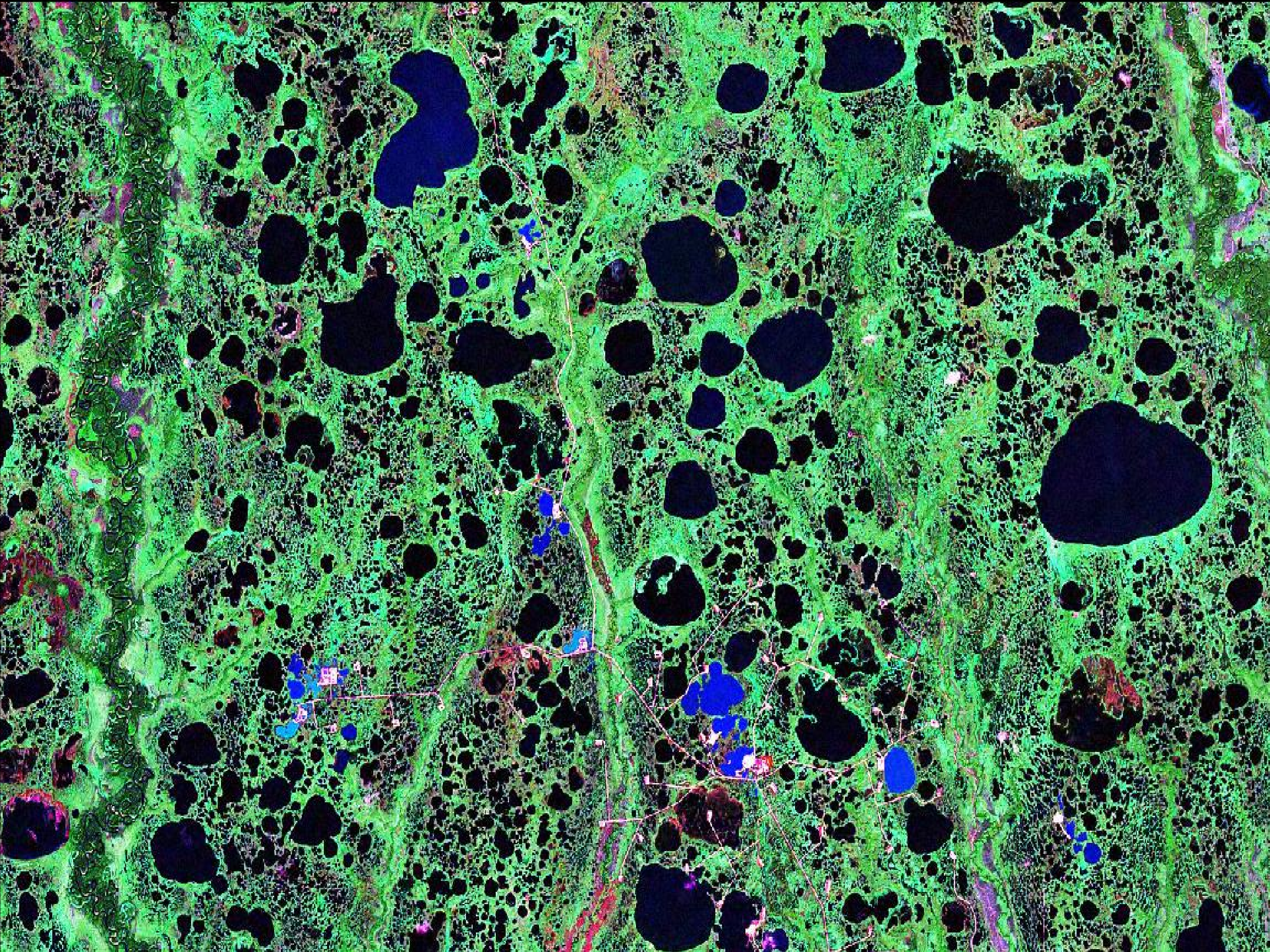


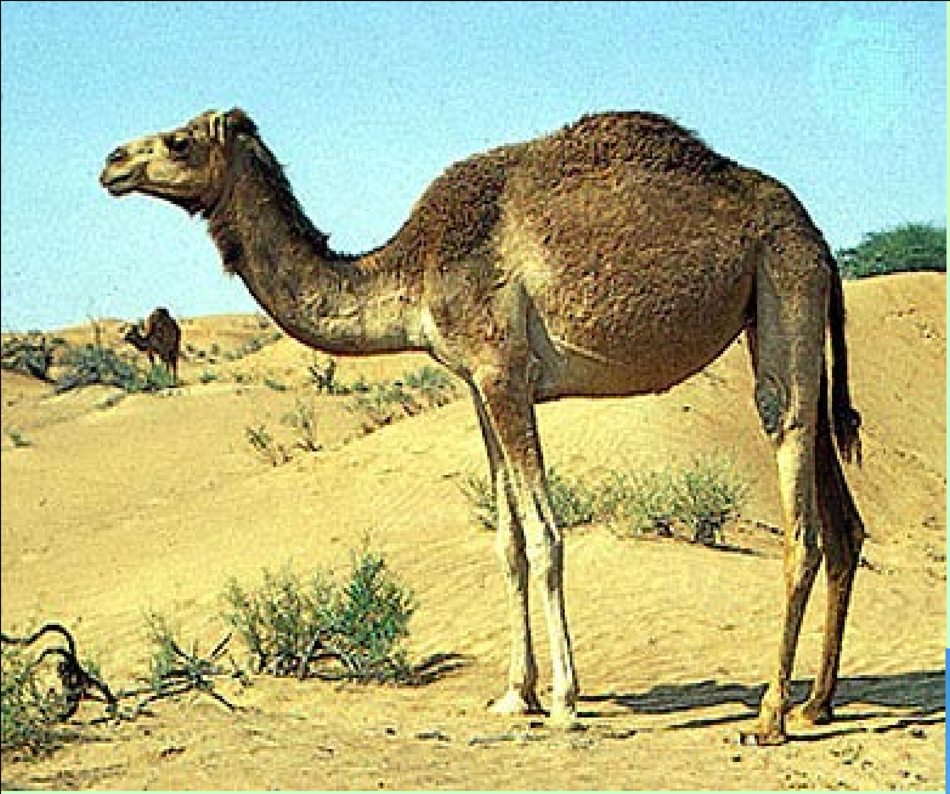
Difficult to measure with satellites

Field trip 2010

Type	Percent of coverage , %	Average temperature, deg Celcius	Depth of permafrost, m
Continuous permafrost			
3	100	less than -13	M >800 m
4	100	-11 to -13	M 500-700 m
5	100	-9 to -11	M 400-600 m, in mountain ridges 1000 m or more
6	100	-7 to -9	M 300-500 m, in mountain ridges up to 500_900 m
7	100	-5 to -7	M 200-400 m, in mountain ridges 300-500
8	100	-3 to -5	M 200-400 m,
9	100	-1 to -3	M 100-300 m
Discontinuous permafrost			
10	70-80	0 to -2, thaw soils - +1 to 0	M up to 100 m, rarely 200-300 m
11	40-60	0 to -1, thaw soils - +2 to 0	M 50-70 m, rarely 100-200 m
12	5-10	0 to -0.5, thaw soils +2 to 0	M 15-20 m, rarely up to 50 m
Zones of constant seasonal freezing of soils			
14	up to 5%	0 to -0.5	M up to 10-20 m

Note the depth: several hundreds of meters !

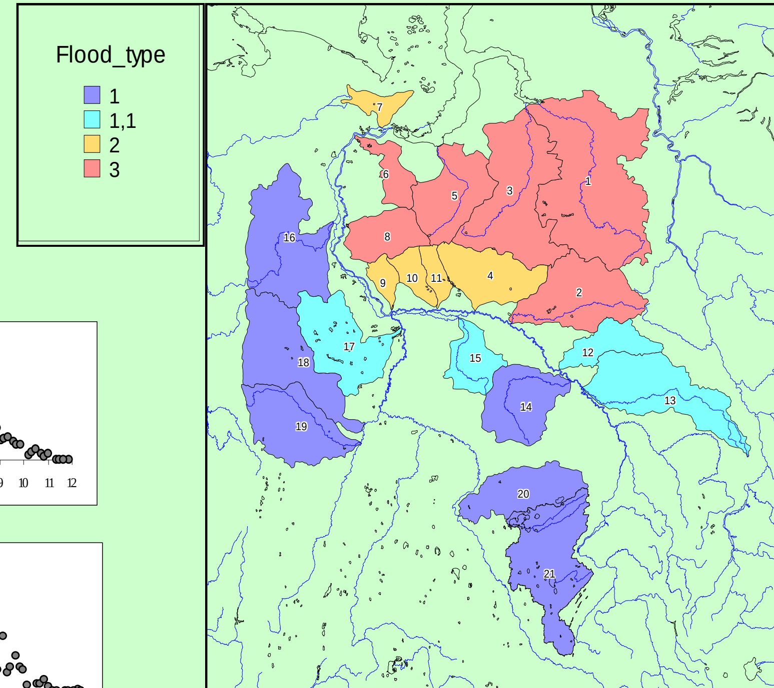




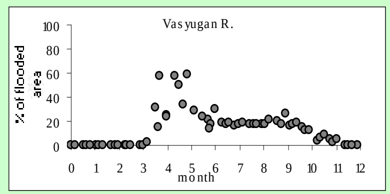
What do we see from backscatter in Siberia?

Wet zones: one- and two-humped came

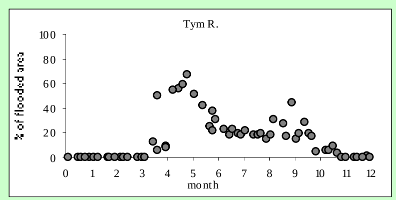
Using ENVISAT data we estimate the extent (%) of wet zones within 21 mid-size watershed of the Ob' river system. Basing on the difference in seasonal signal we grouped the watersheds into the 3 main types (and one subtype)



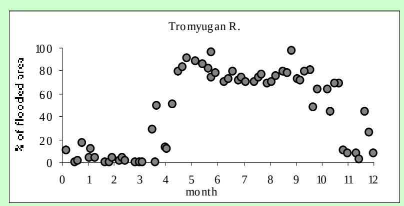
Type 1: Small permanent flooding (one peak) and well pronounced draining



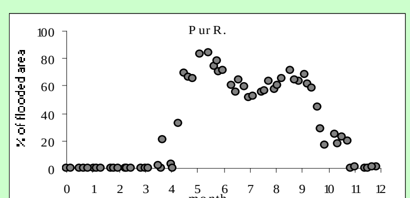
Type 1a: Same as 1 but with two peaks



Type 2: High permanent flooding with insignificant draining



Type 3: Medium permanent flooding with two peaks and well pronounced draining

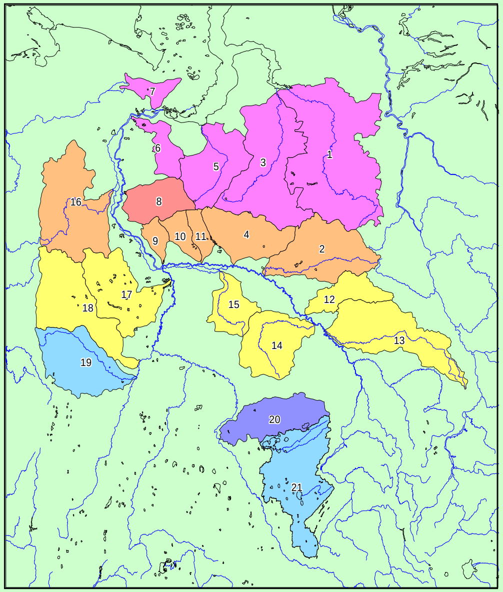


No River name

1 Taz
2 Vakh
3 Pur
4 Trom Yugan
5 Nadym
6 Poluy
7 Schuchya
8 Kazym
9 Nazym
10 Lyamin
11 Pim
12 Tym
13 Ket
14 Vasyugan
15 Big Yugan
16 Severnaya Sosva
17 Konda
18 Tavda
19 Tura
20 Om
21 Inner watershed

Wet zones: timing of seasonal variations

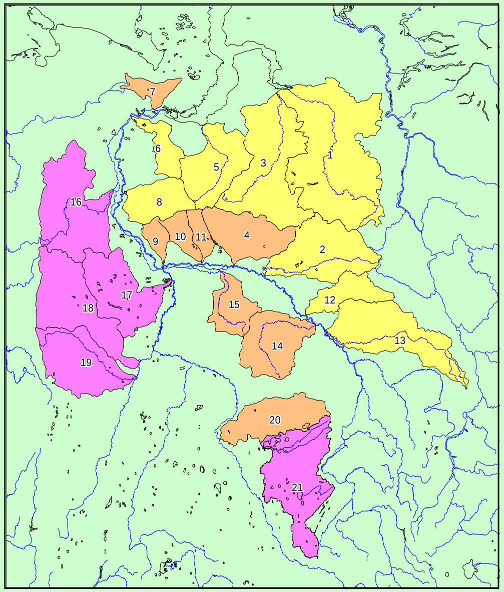
Beginning of flood



Flood start

- Mid March
- End of March
- Beginning of April
- Mid April
- End of April
- Beginning of May

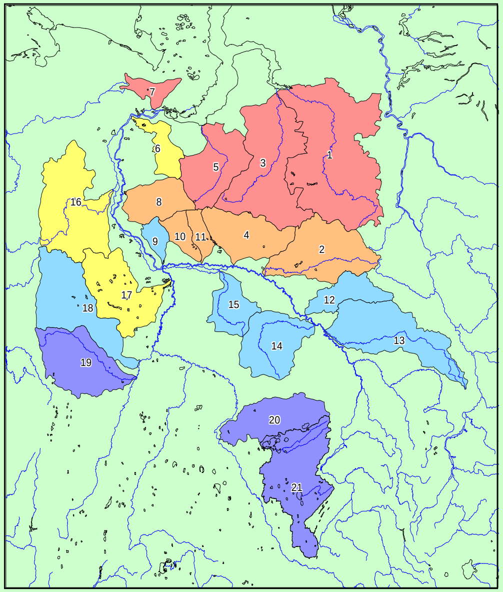
Beginning of freeze-up



Freeze start

- Beginning of October
- Mid October
- Beginning of November

Maximal flood

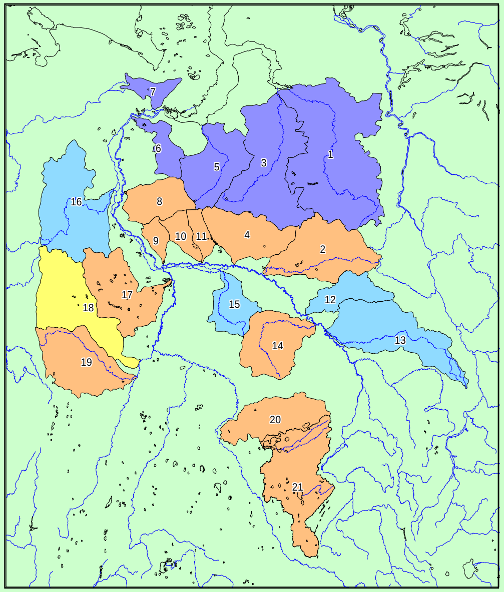


Maximal flood

- Mid April
- Beginning of May
- Mid May
- End of May
- Beginning of June

Full freeze-up

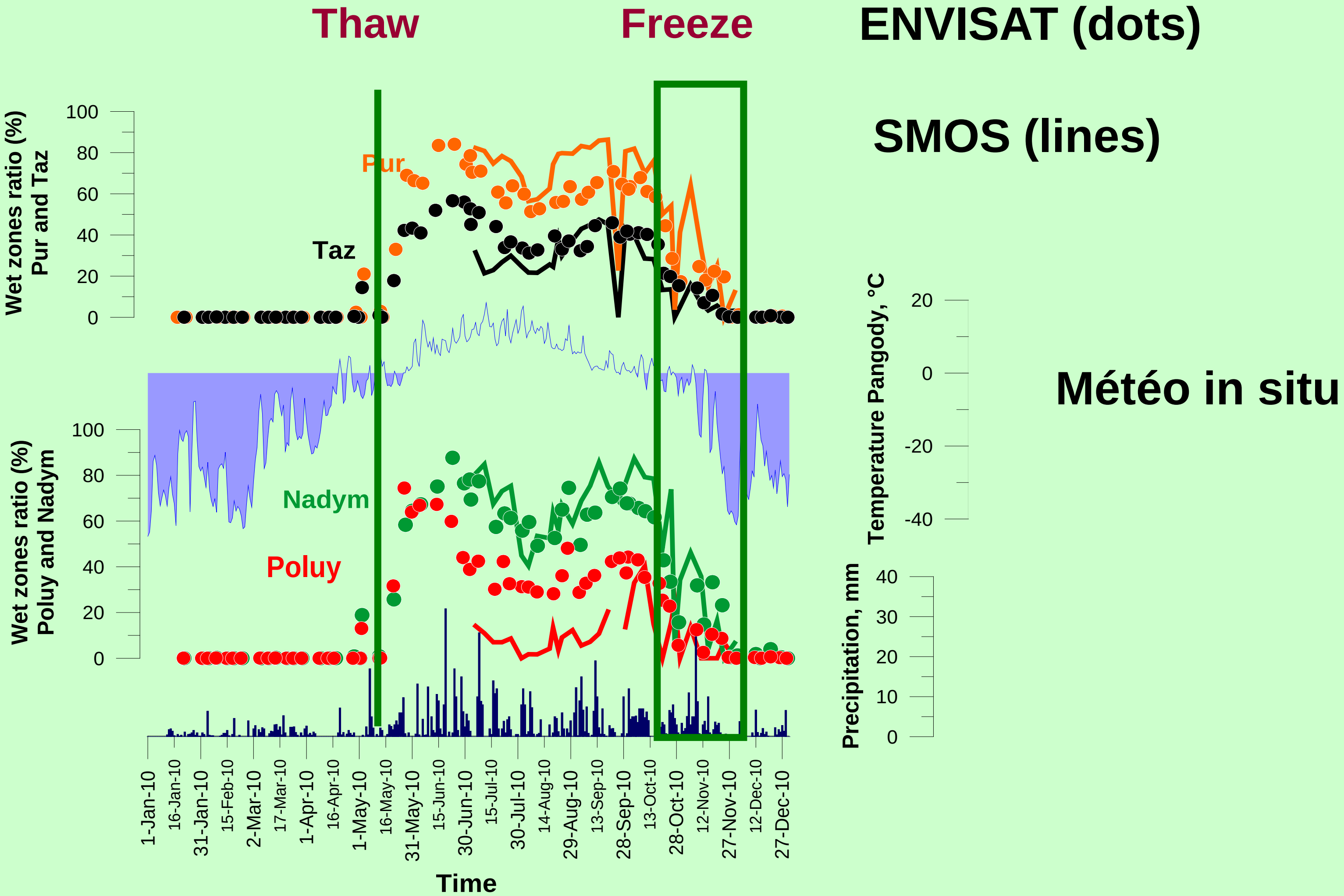
Generally N to S, but some specific orographic/drainage features



Full freeze

- Mid November
- End of November
- Beginning of December
- Mid December
- End of December

Freeze/Thaw of bogs and lakes



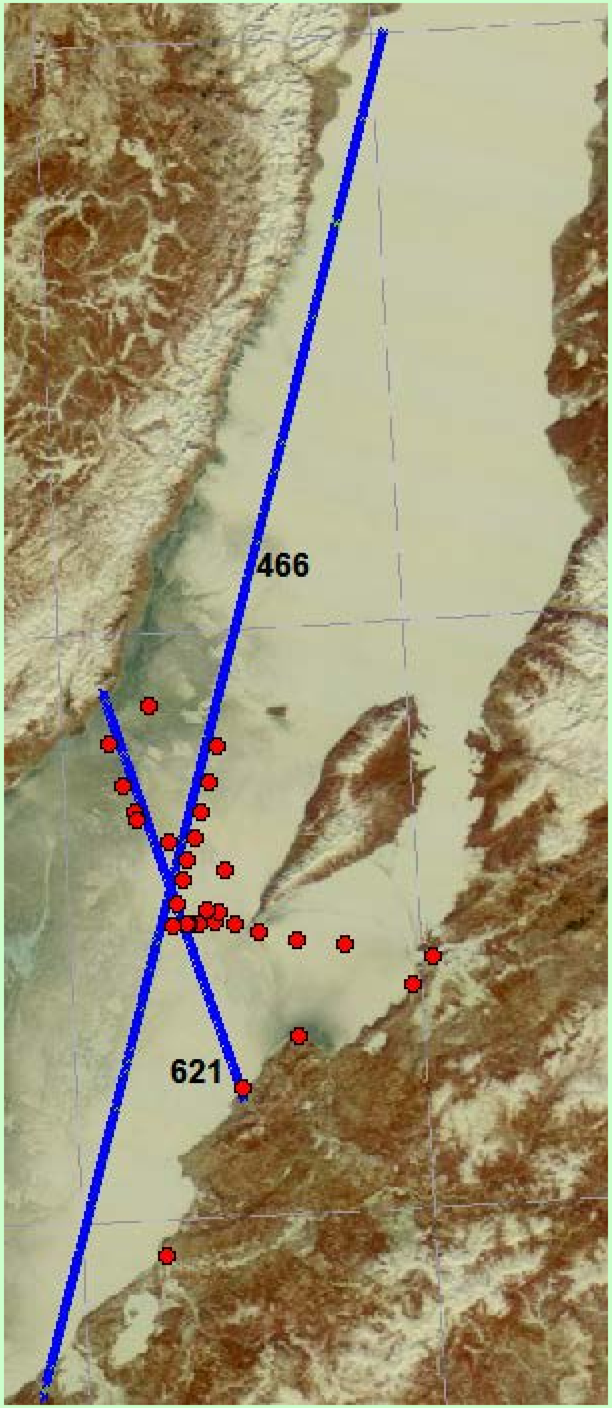
AltiKa-AltiKu-AltiS

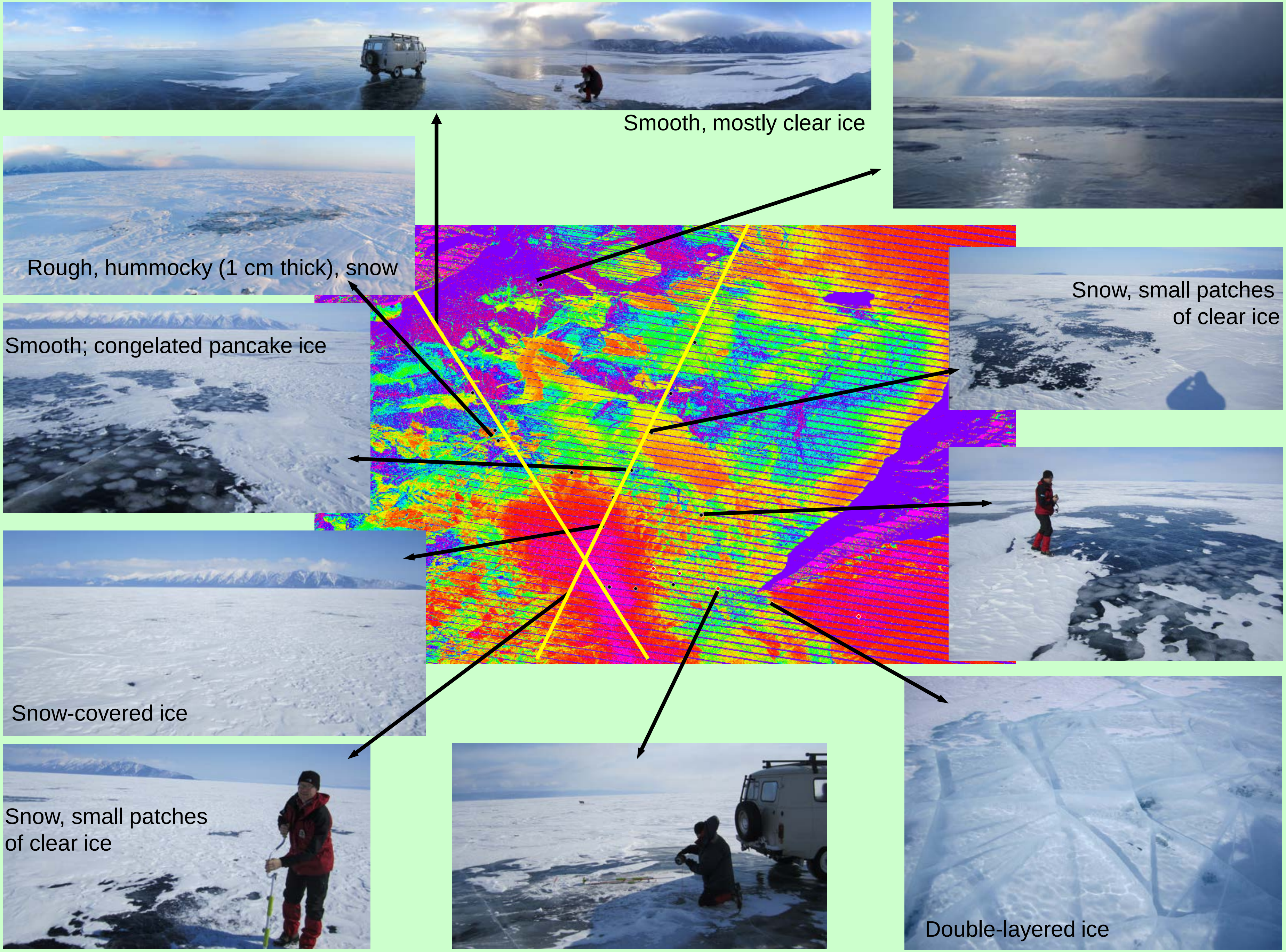
Winter 2012/2013 - a lot of snow

Ice dynamics in real time

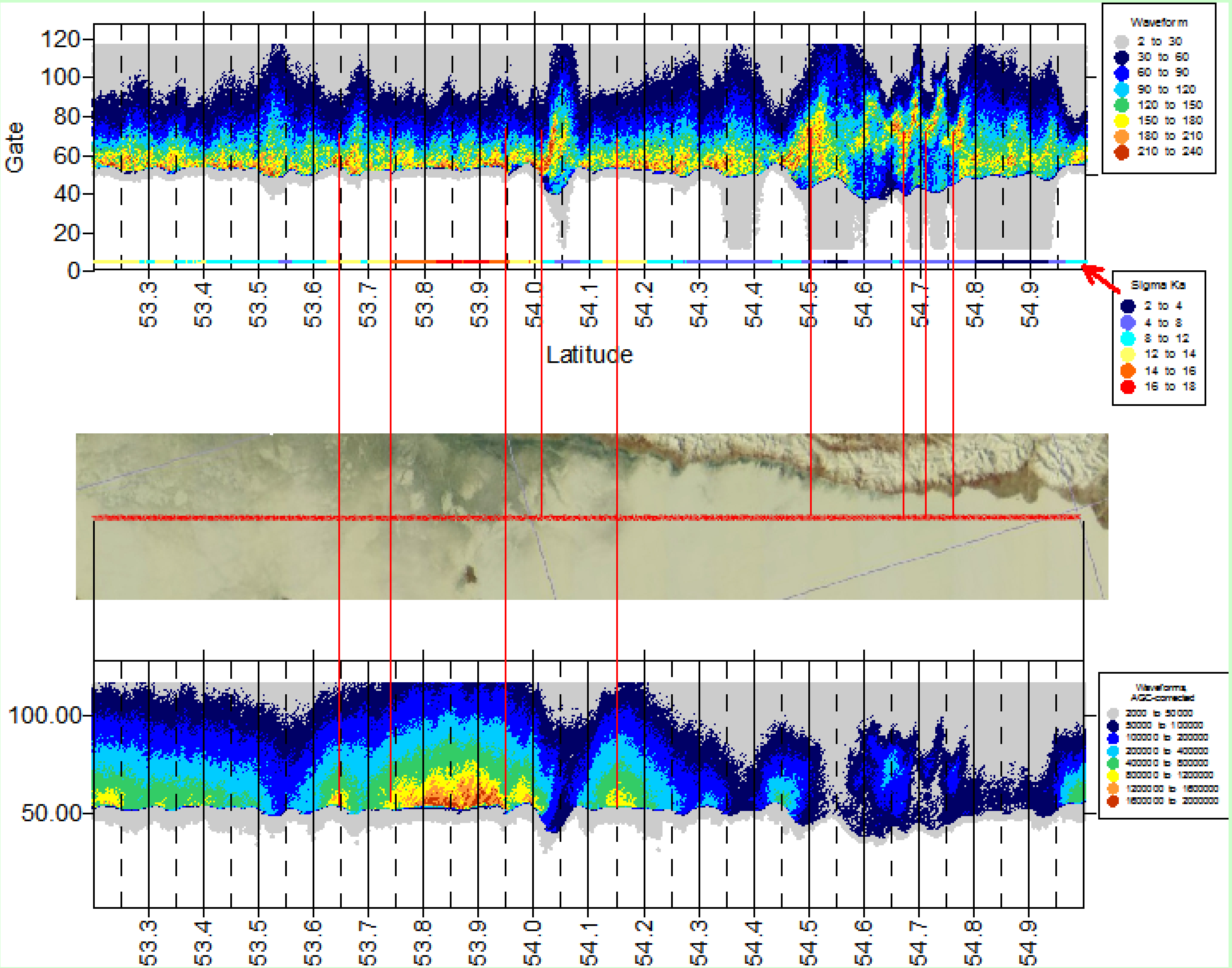

A secondary ice fracture (formed 10 min ago)
Width - 6 cm, ice thickness 110 cm, level difference - 2 cm

Larger expansion crack, hummocks 50-60 cm high

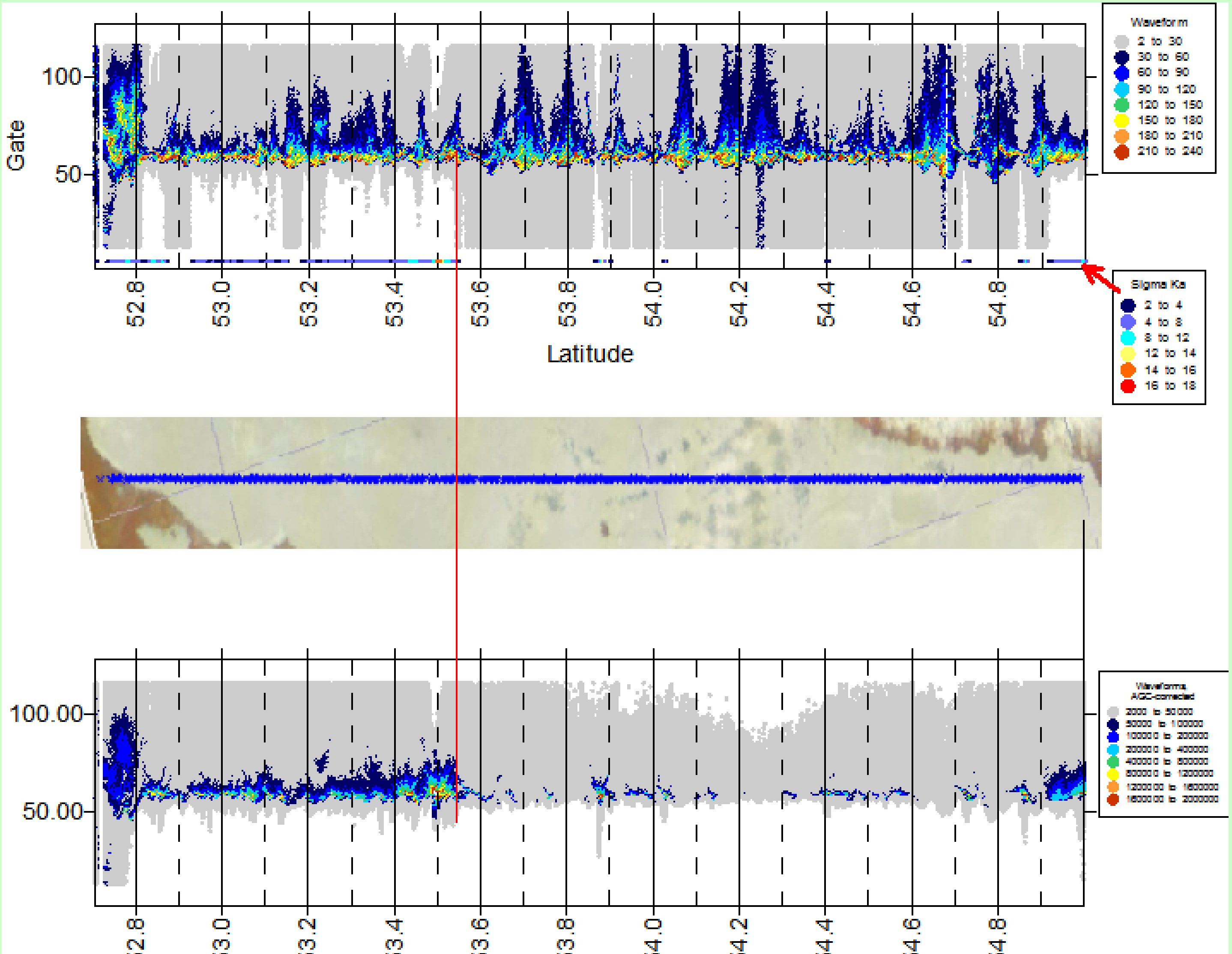

466
621


Smooth, mostly clear ice
Rough, hummocky (1 cm thick), snow
Smooth; congelated pancake ice
Snow, small patches of clear ice
Snow-covered ice
Snow, small patches of clear ice
Double-layered ice

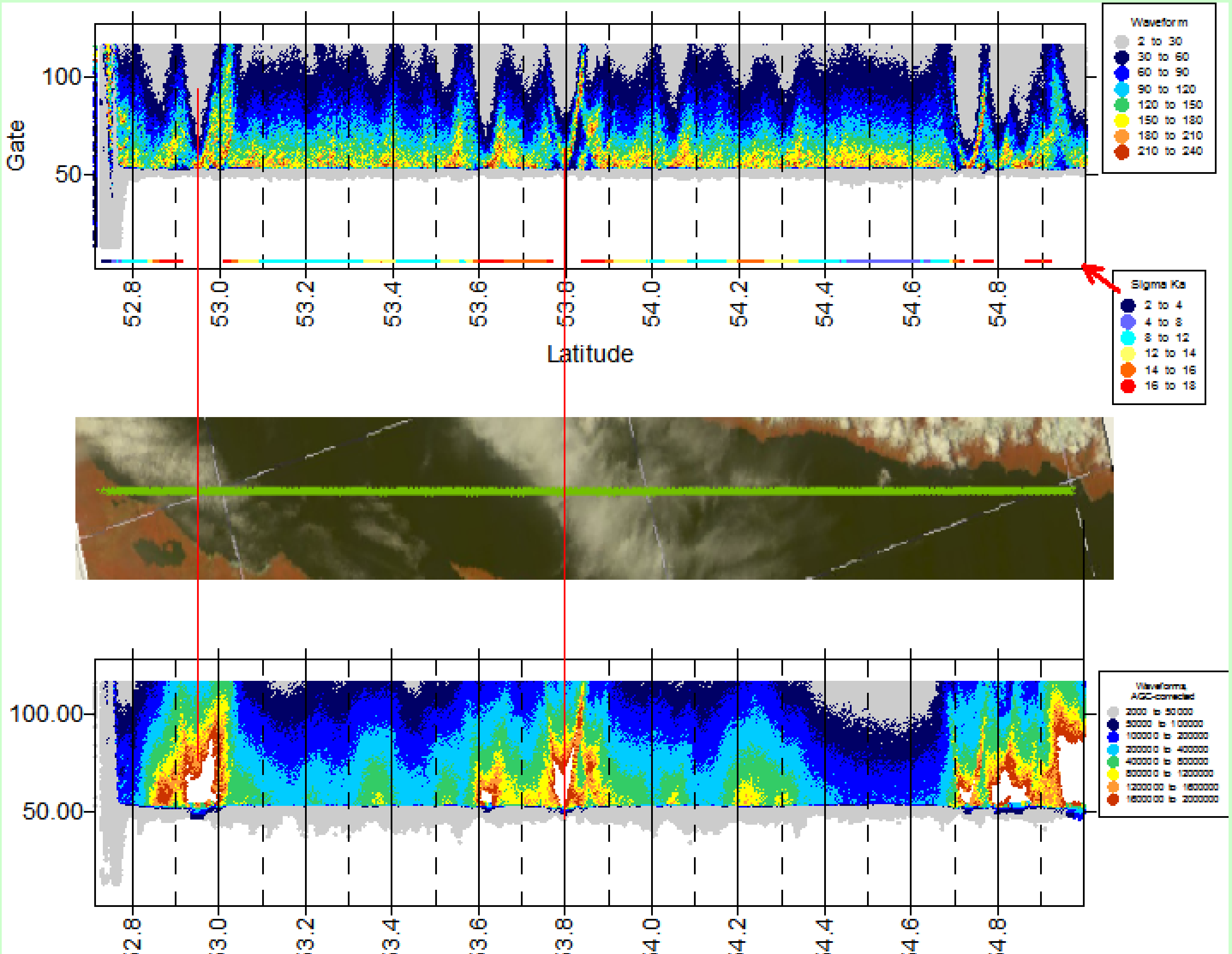
466, cycle 1, 30 March 13



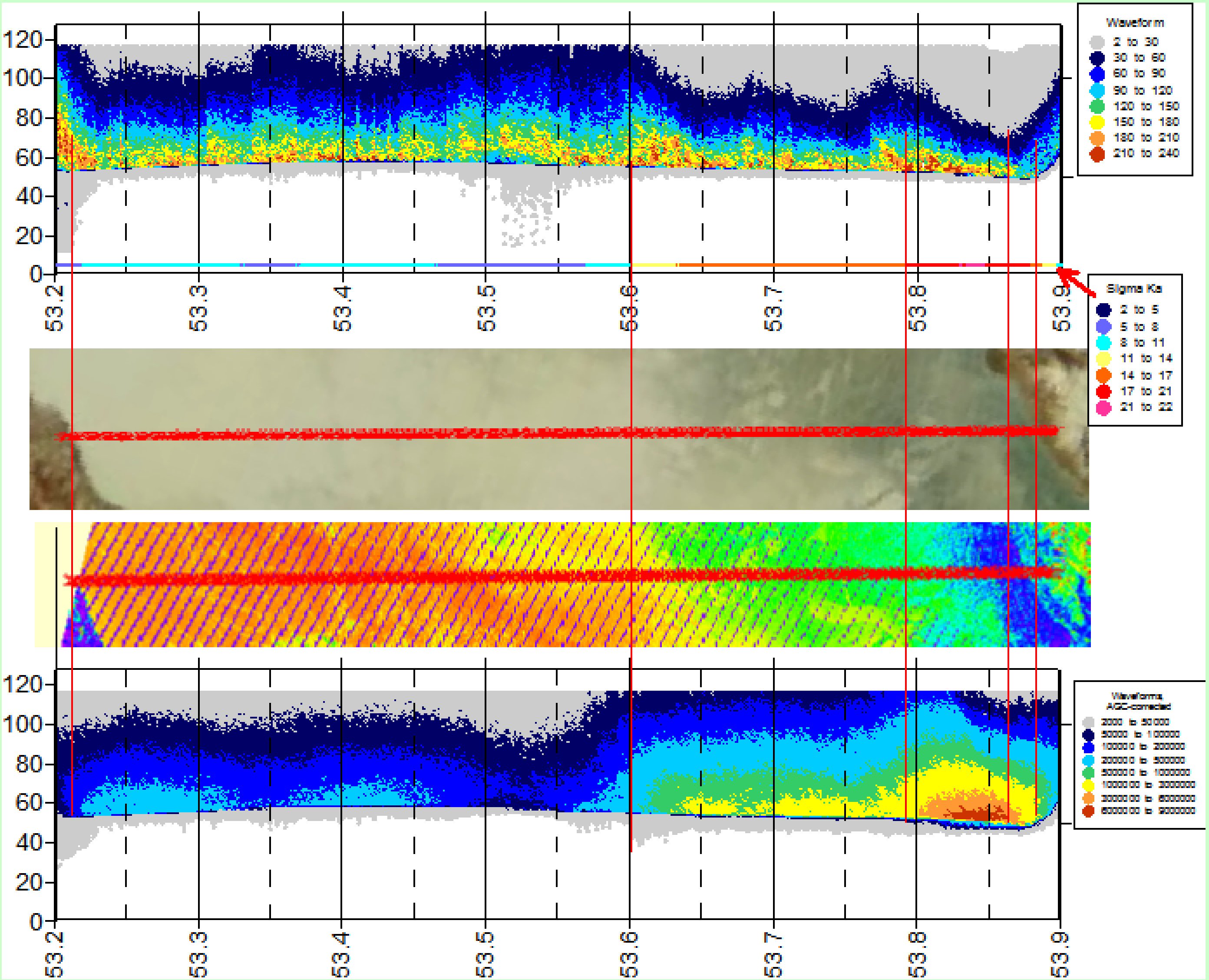
466, cycle 2, 4 May 13



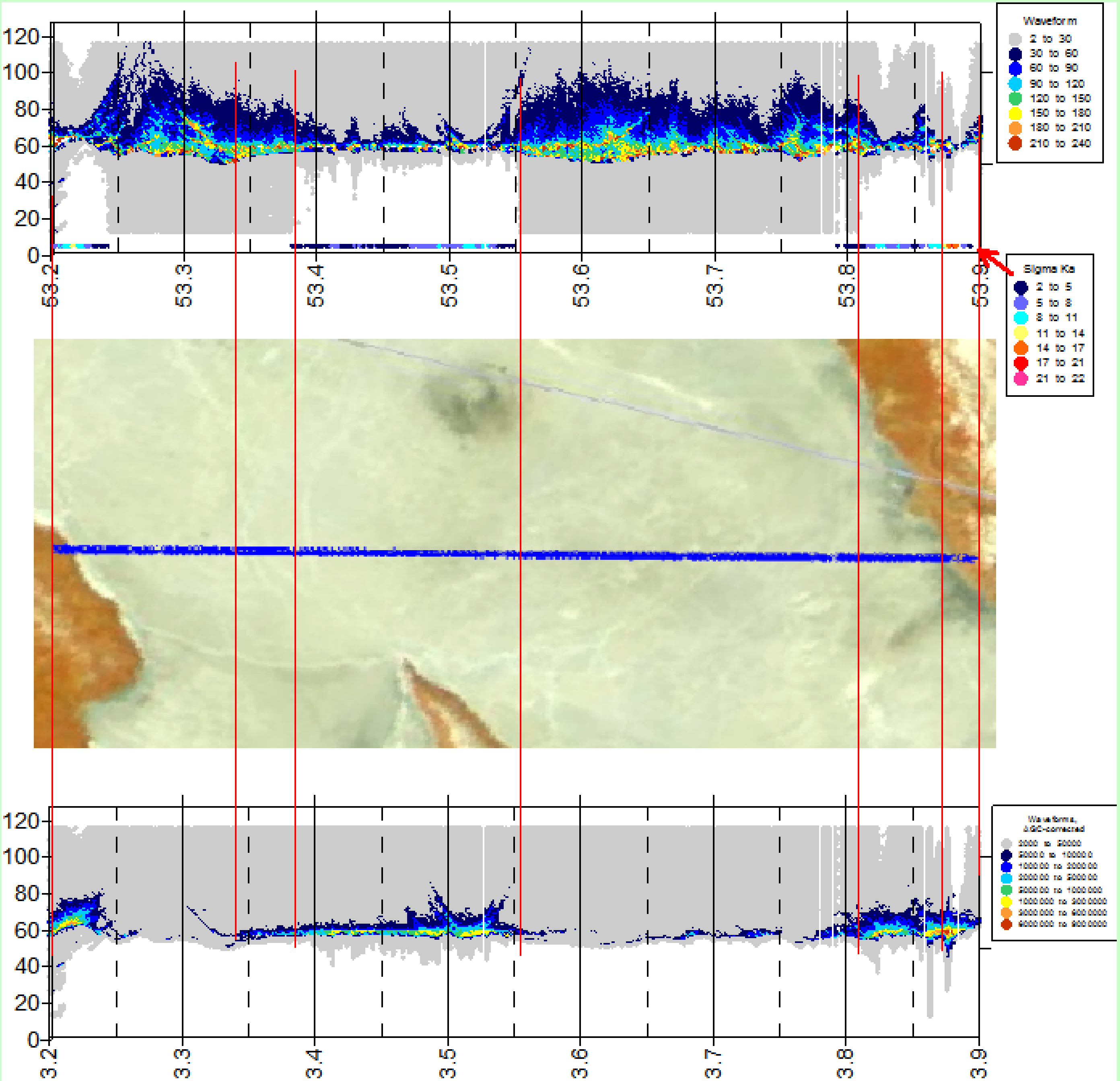
466, cycle 3, 8 June 13

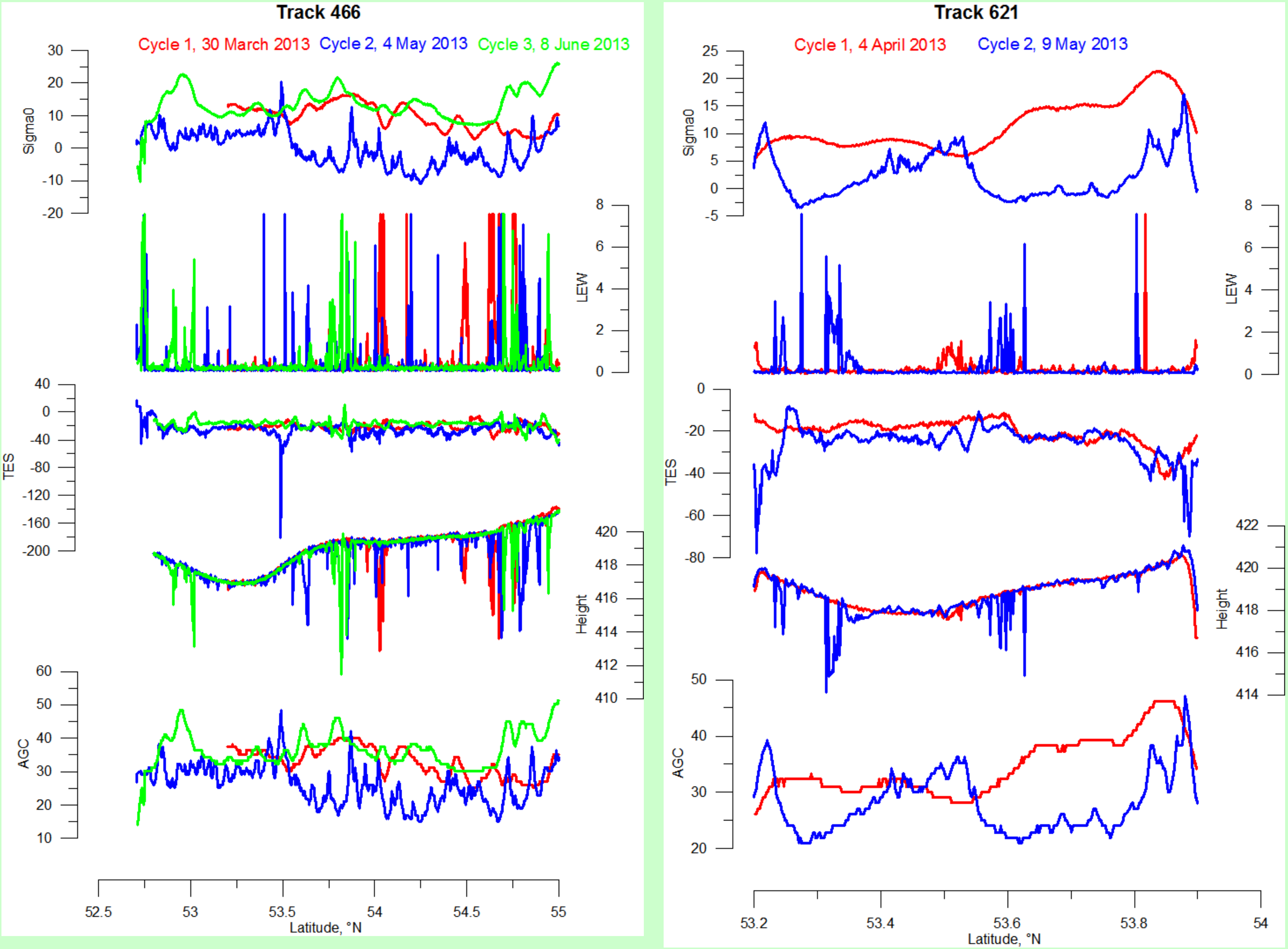


621, cycle 1, 4 April 13



621, cycle 2
9 May 13

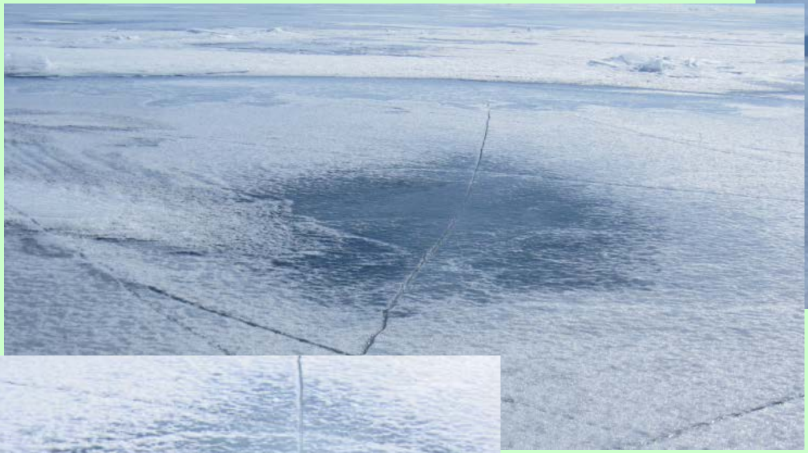


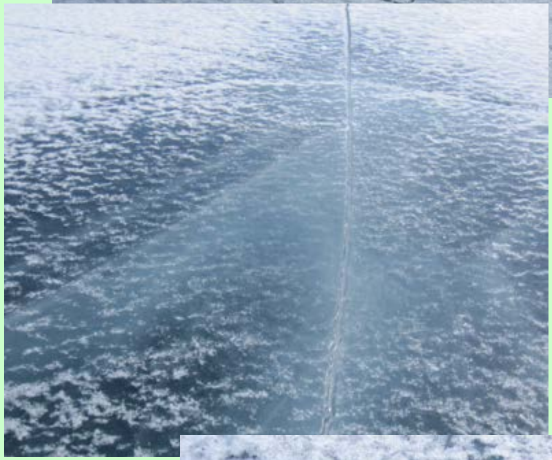


Track 466
Cycle 1, 30 March 2013
Cycle 2, 4 May 2013
Cycle 3, 8 June 2013
Sigma0
LEW
TES
Height
AGC
Latitude, °N
Track 621
Cycle 1, 4 April 2013
Cycle 2, 9 May 2013

Ice
thinning
methamorphism
structure

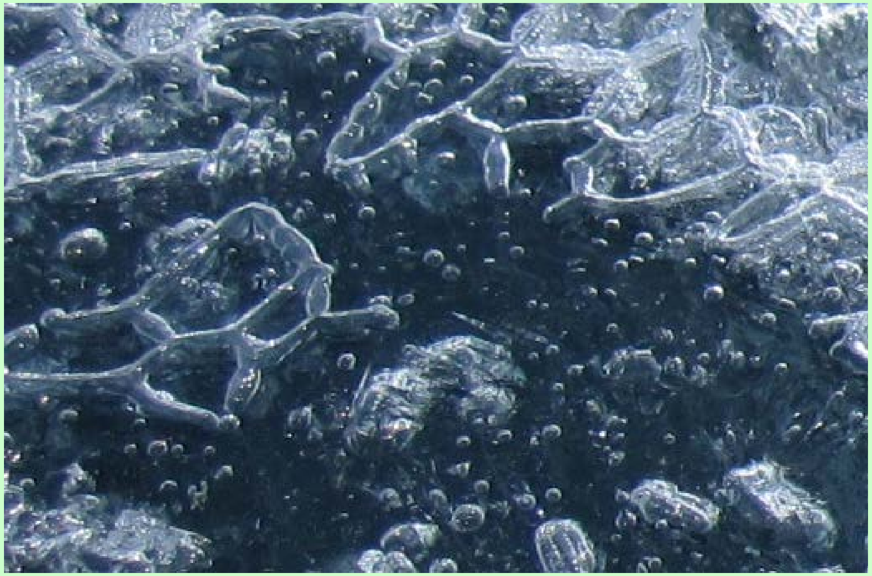
Ice structure

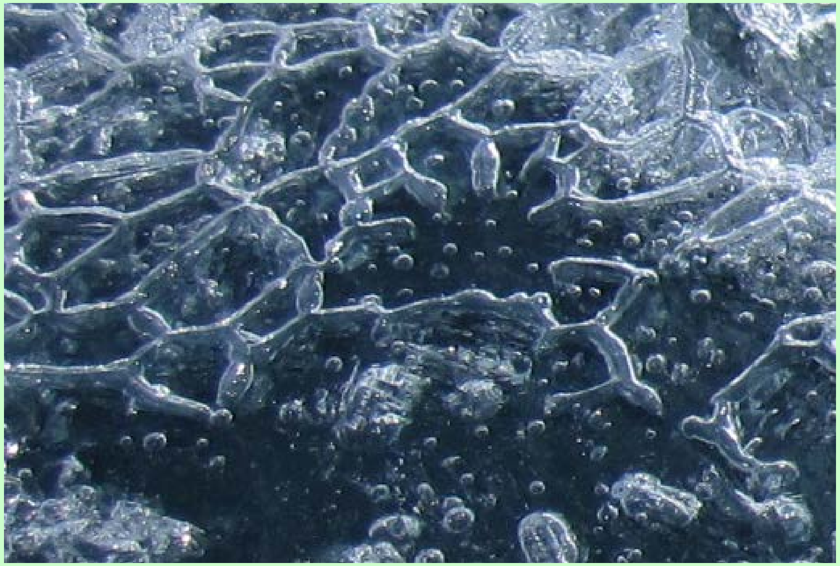




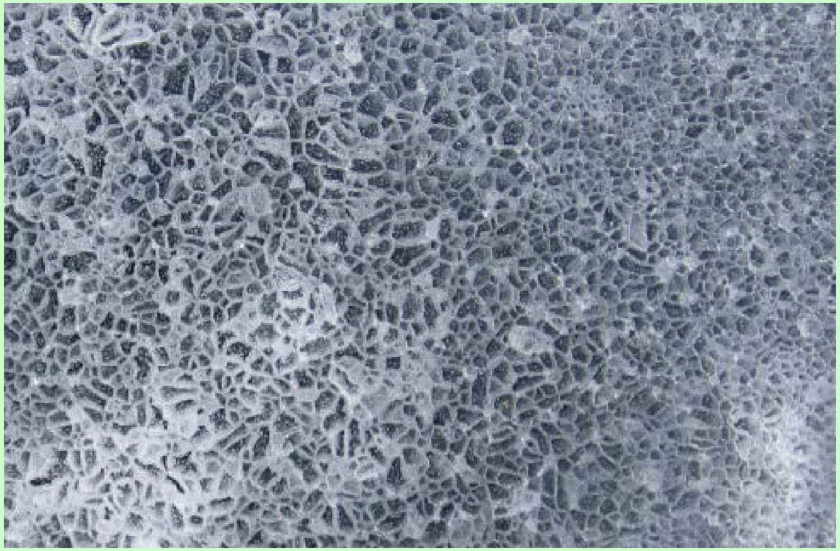
Air channels

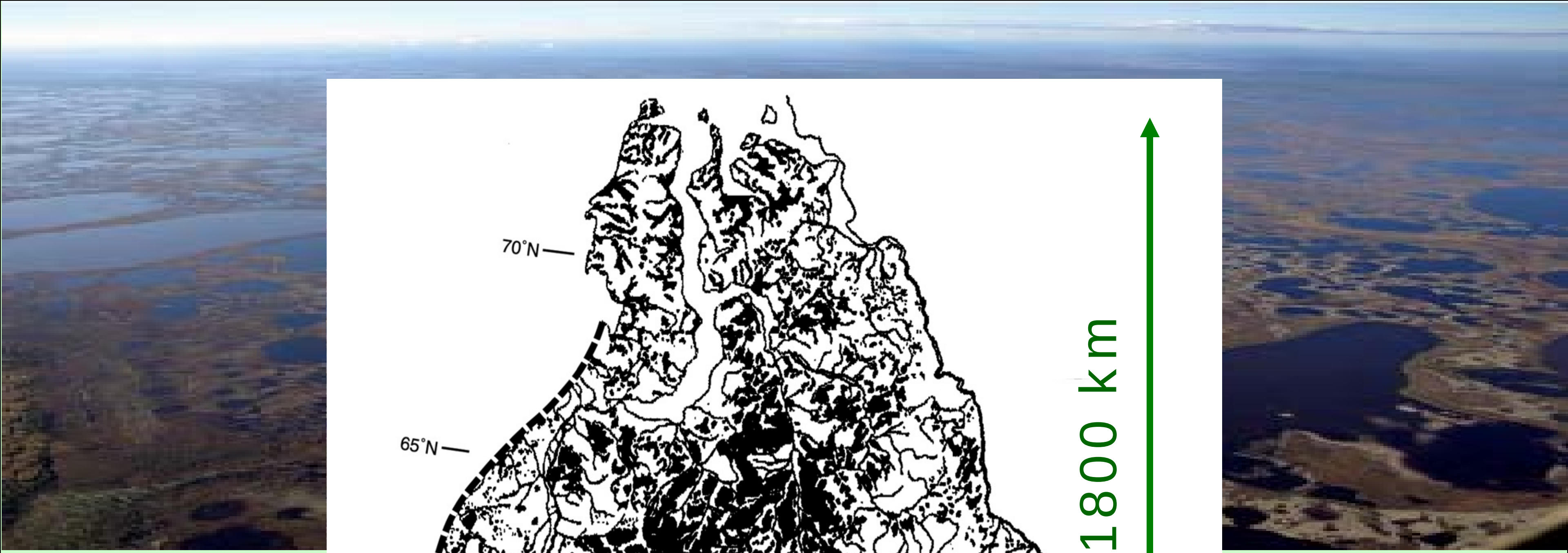
Air channels formation in 9 min
Influence on albedo!



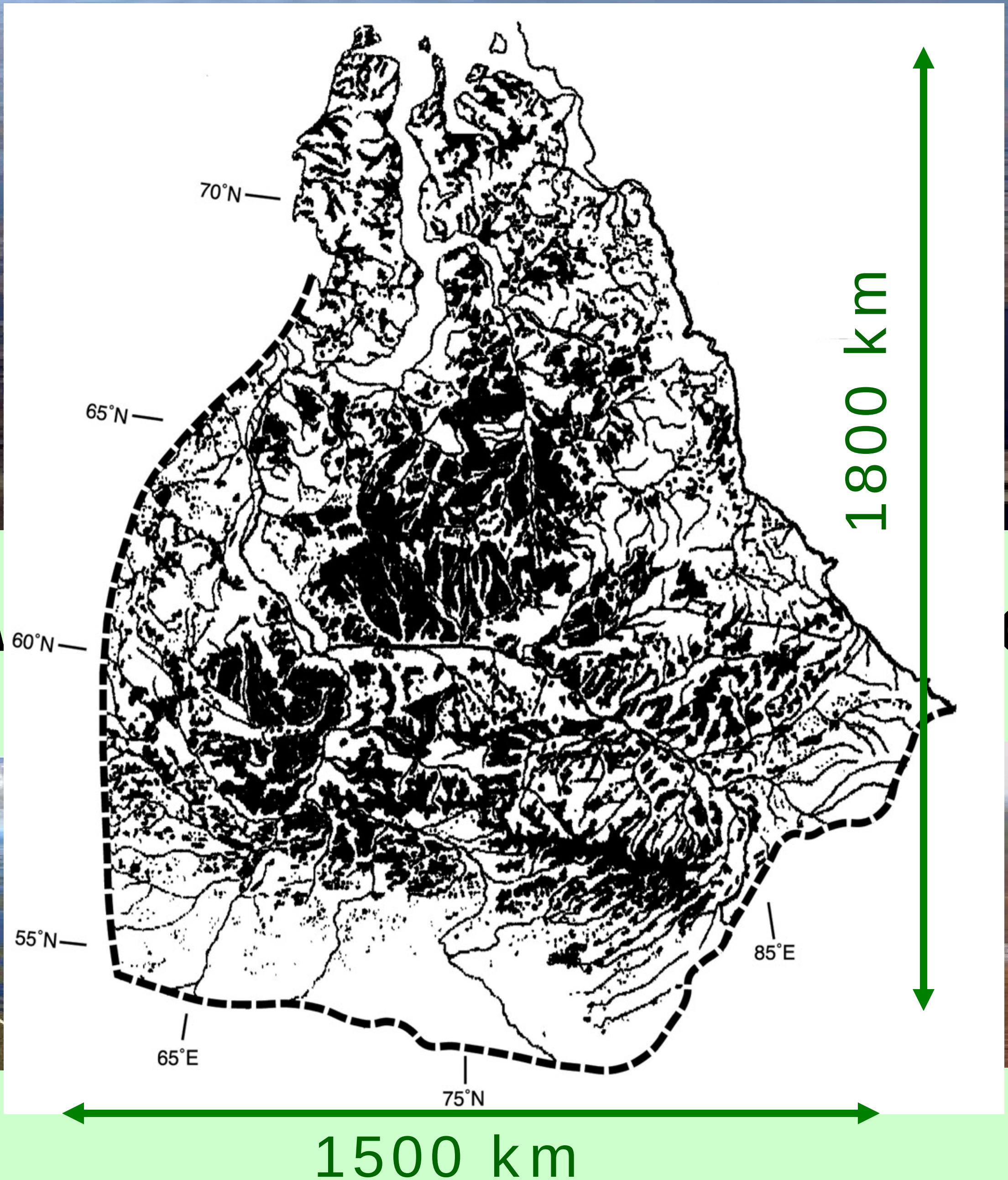


Needle ice



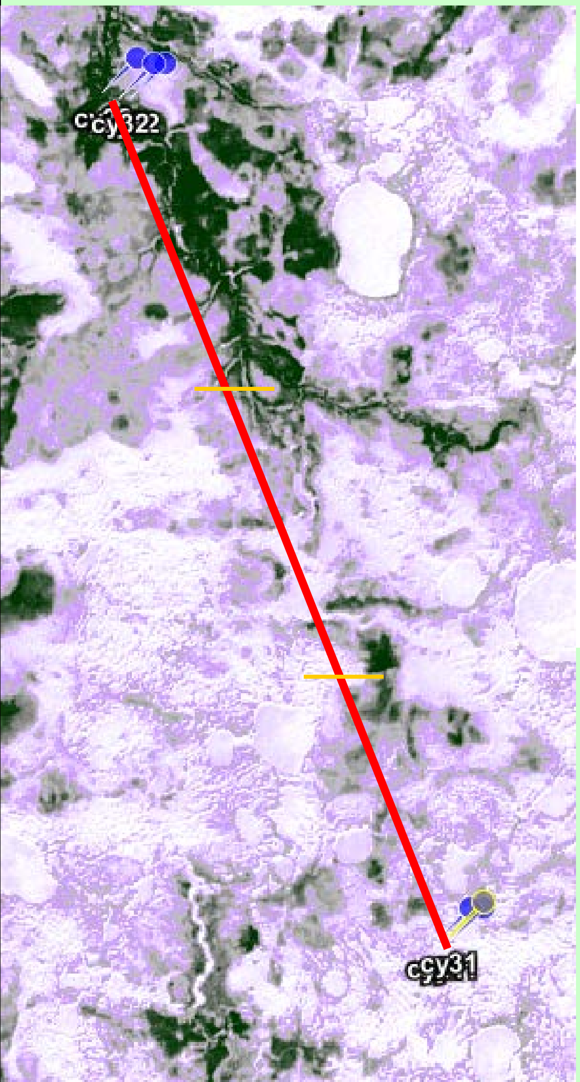


W ds

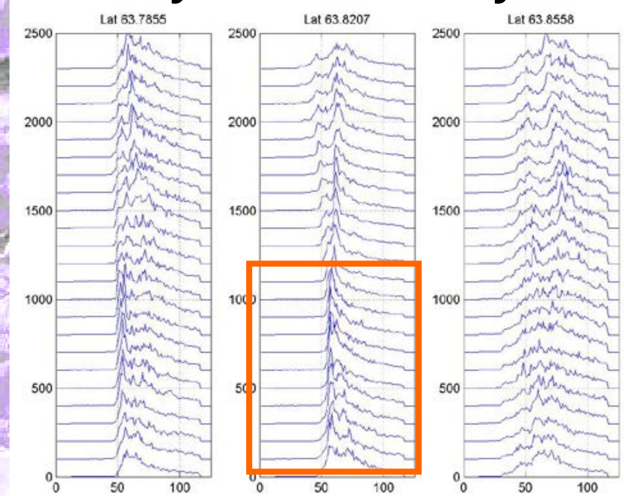


ALTIKA over wetlands

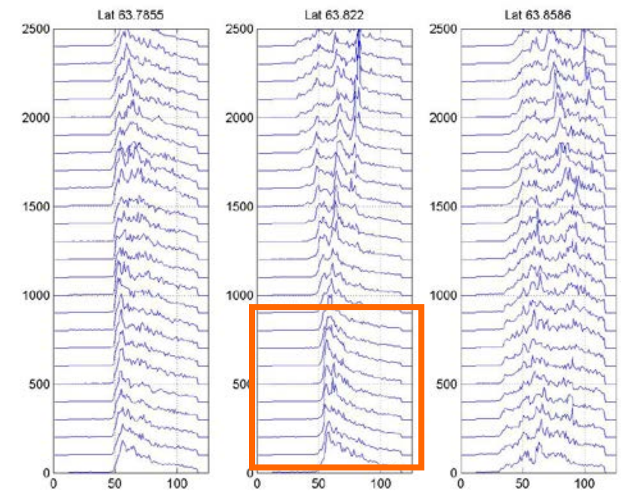
AltiKa waveforms
track 51



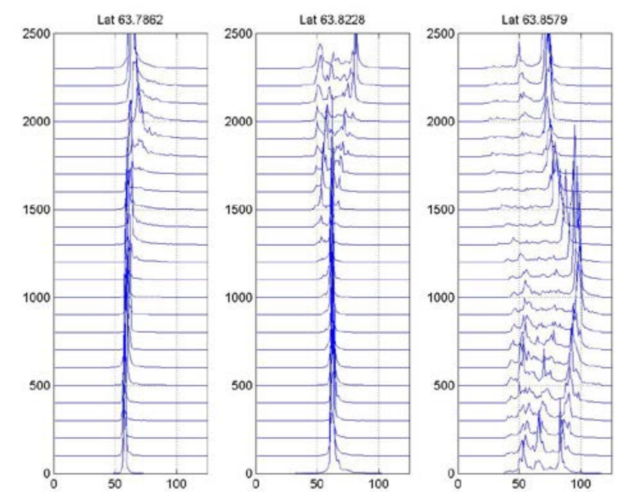
cycle 1, snowy



cycle 2, snowy



cycle 3, melting



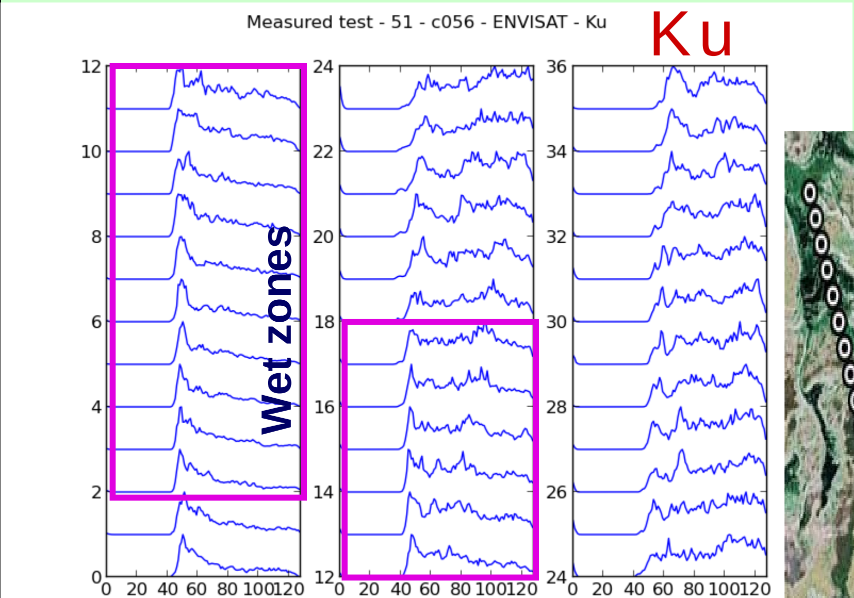
Water/ice dominated footprints - specular waveforms

possibility of freeze/wetness/level studies

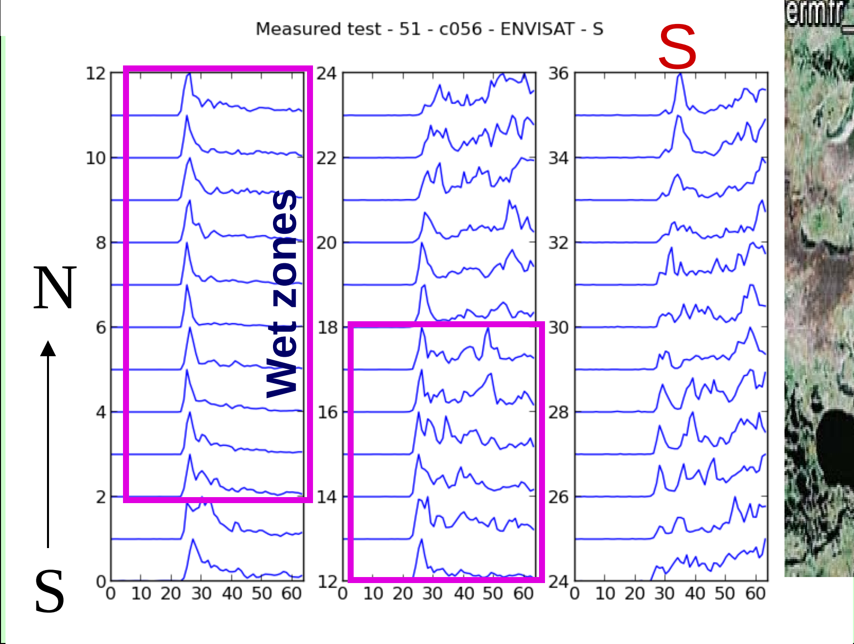
ALTIKA - ENVISAT over snowy/icy wetlands

ENVISAT, February

Ku

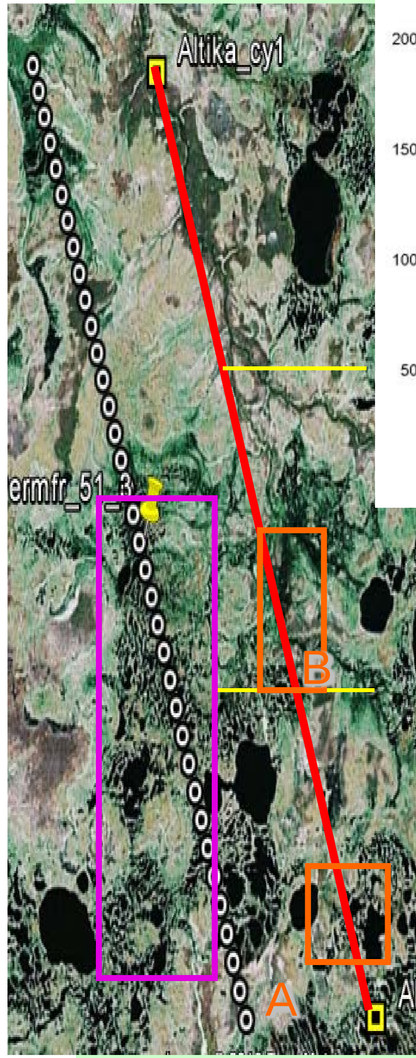


S



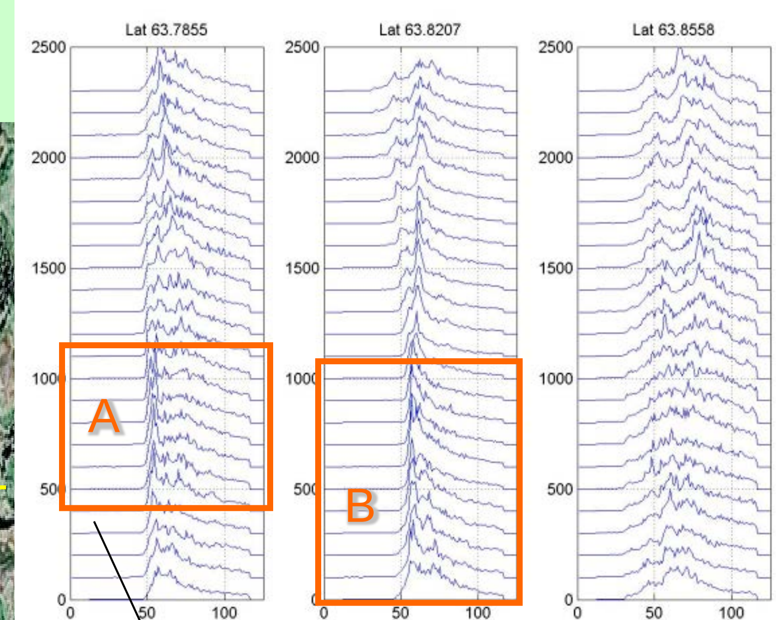
N

S



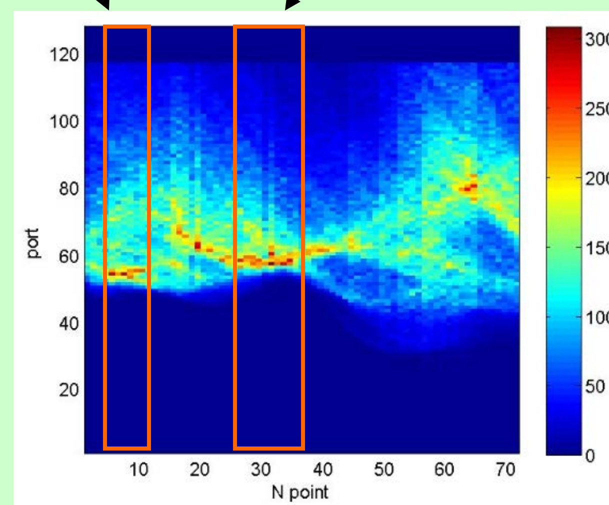
ALTIKA, April

Ka



Wet zones

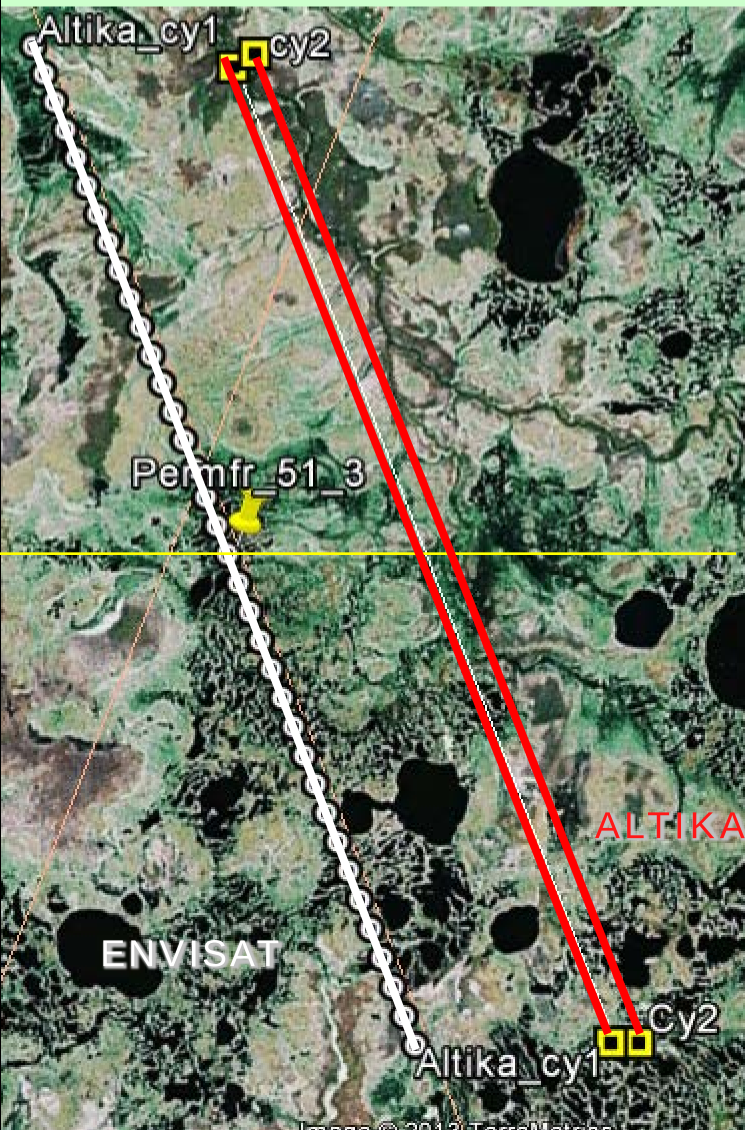
Ka



ALTIKA - ENVISAT over snowy/icy wetlands

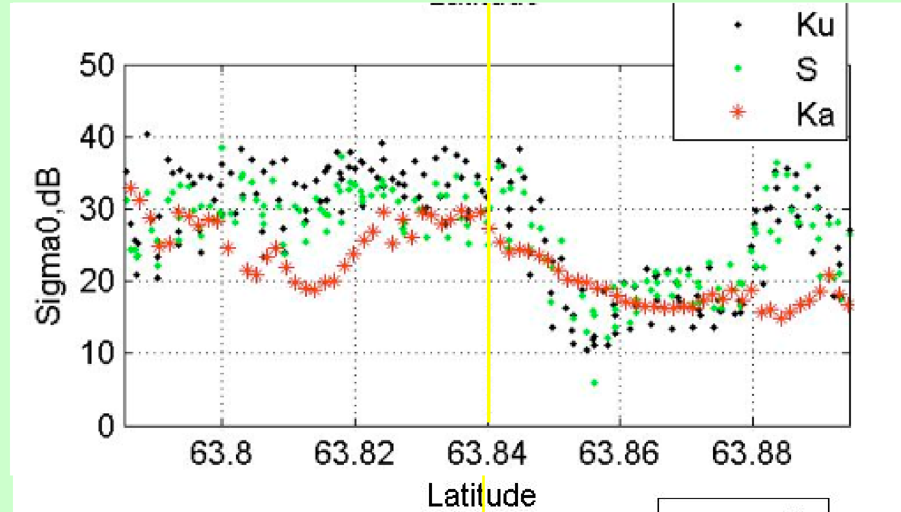
Backscatter, dB

transect of 13 km

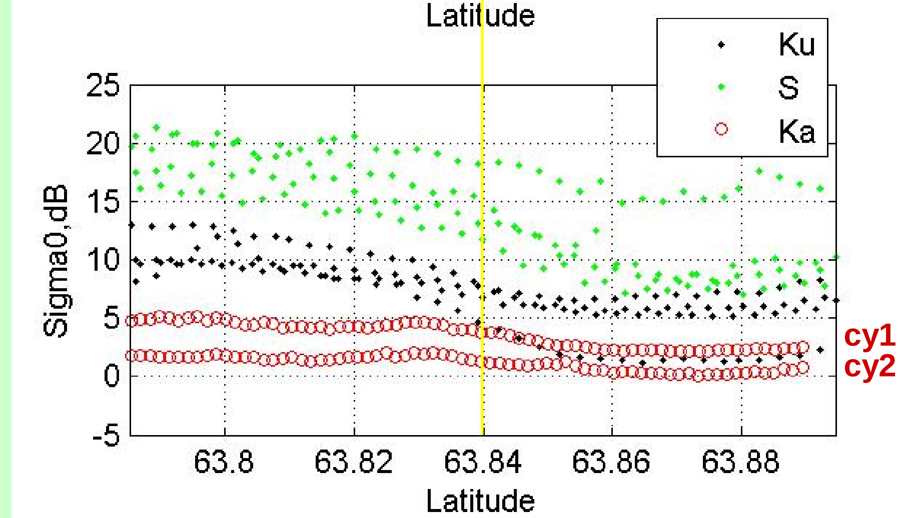


63.84°N

June



April



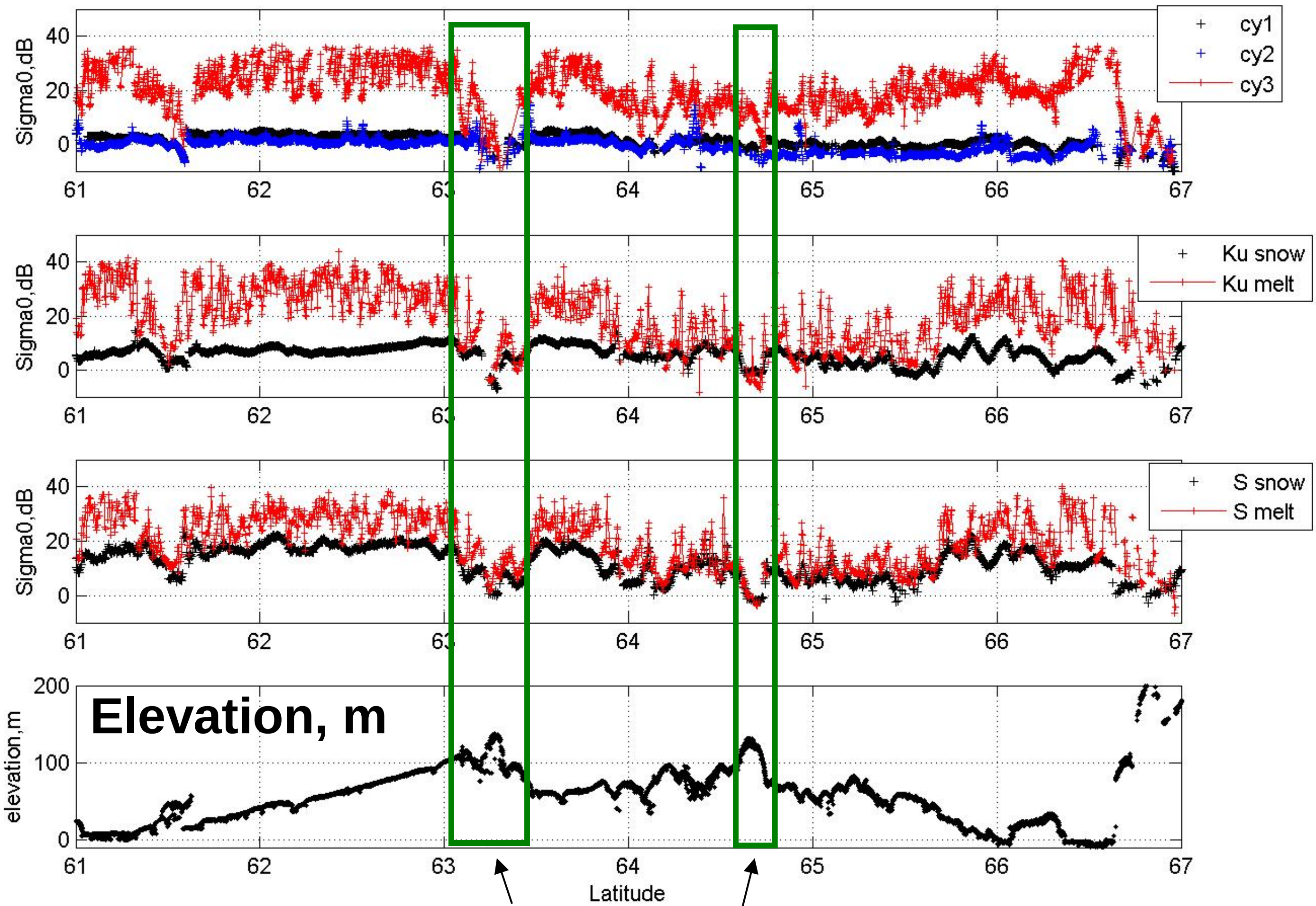
** ENVISAT april cycles before 2008*

Distance between ENVI-Altika tracks = 2,5 km

ALTIKA - ENVISAT over wetlands

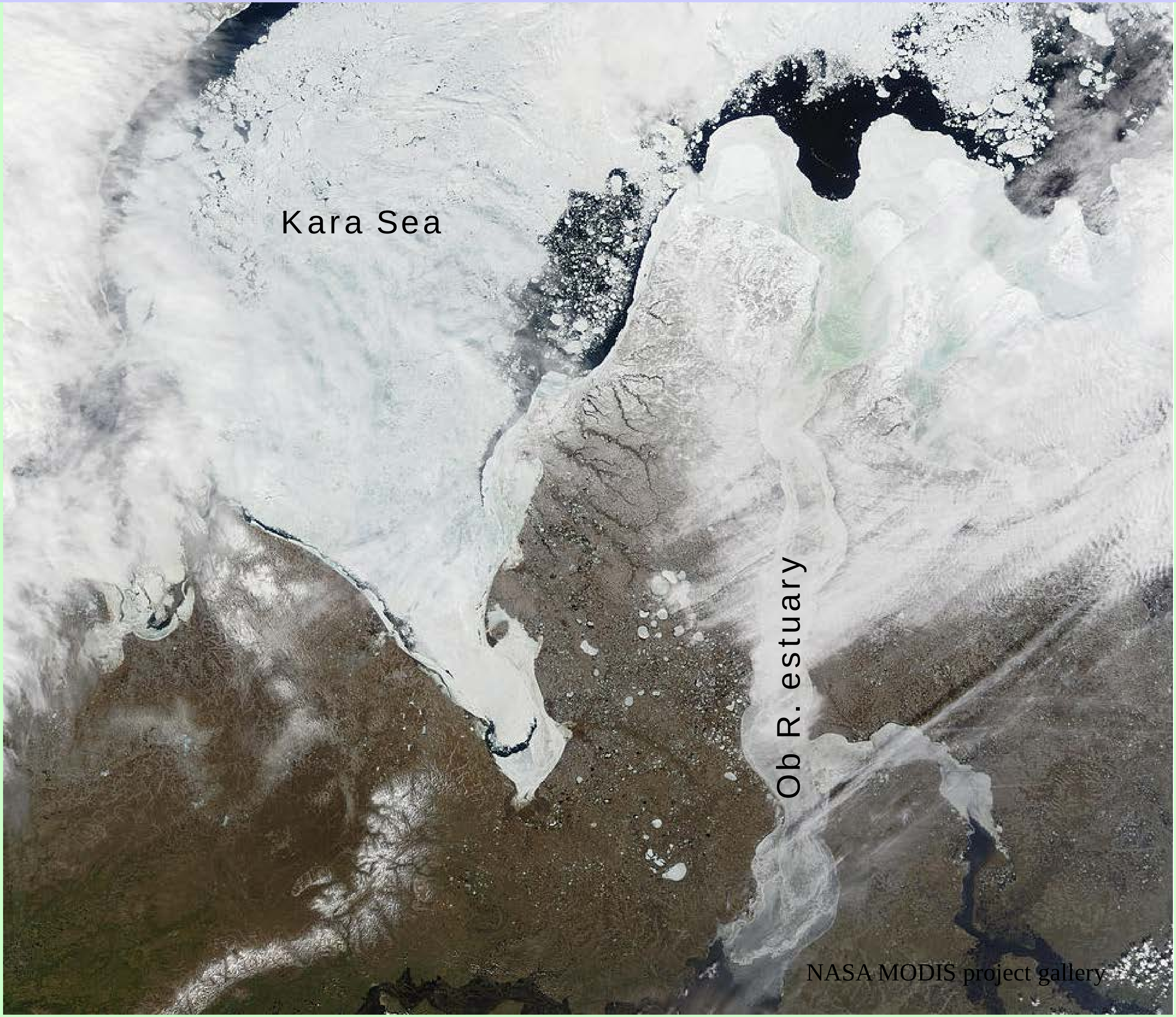
April to June

It is not a noise - these are bogs/lakes



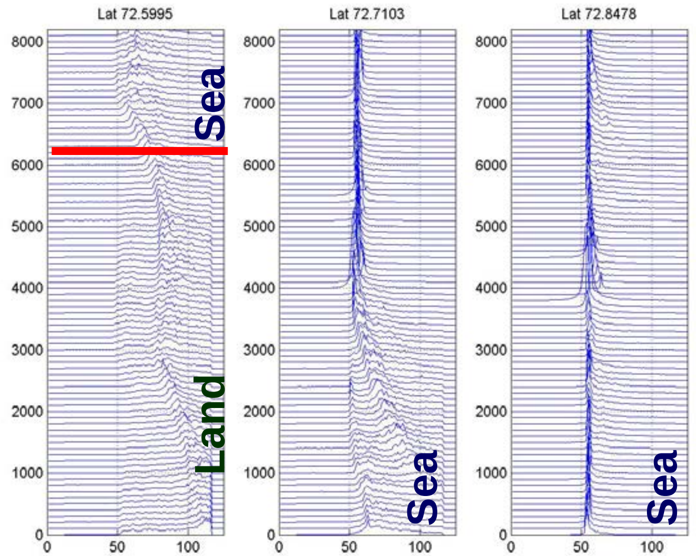
Dry hills

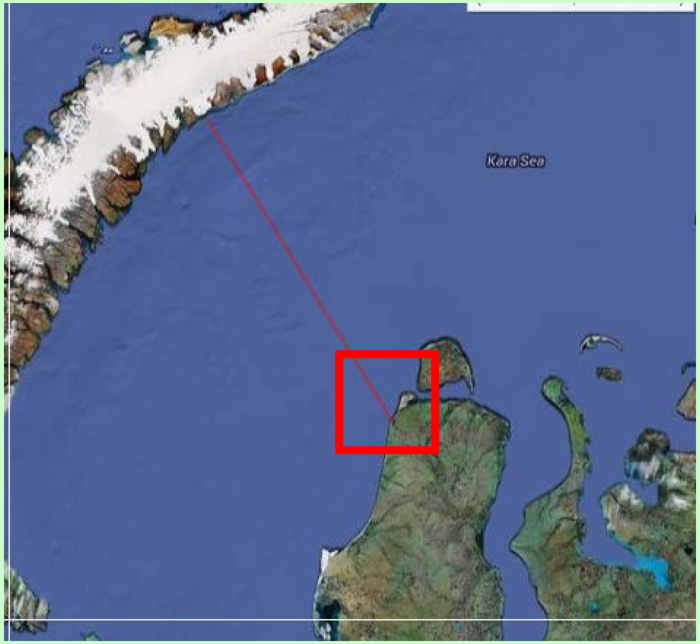
ALTIKA over Kara Sea



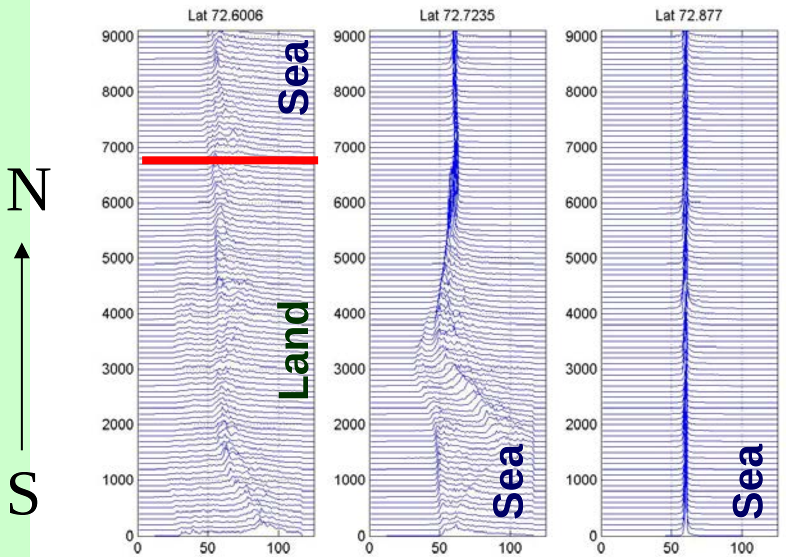
ALTIKA over Kara Sea : waveformes

cycle 1, ice

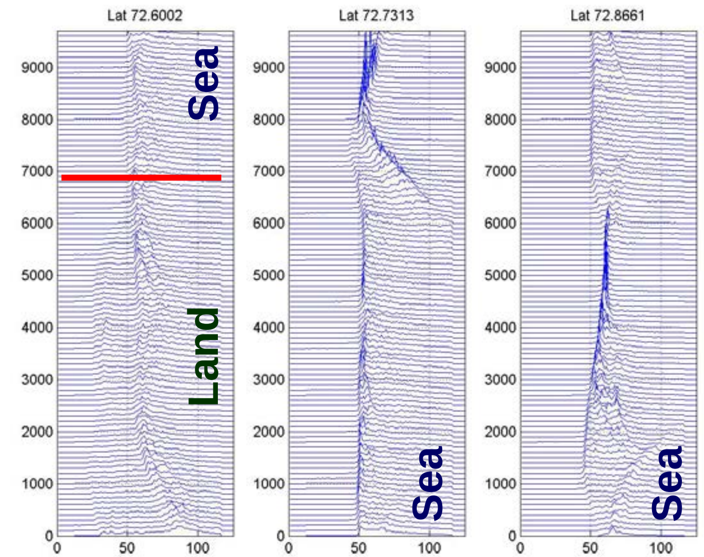




cycle 2, ice

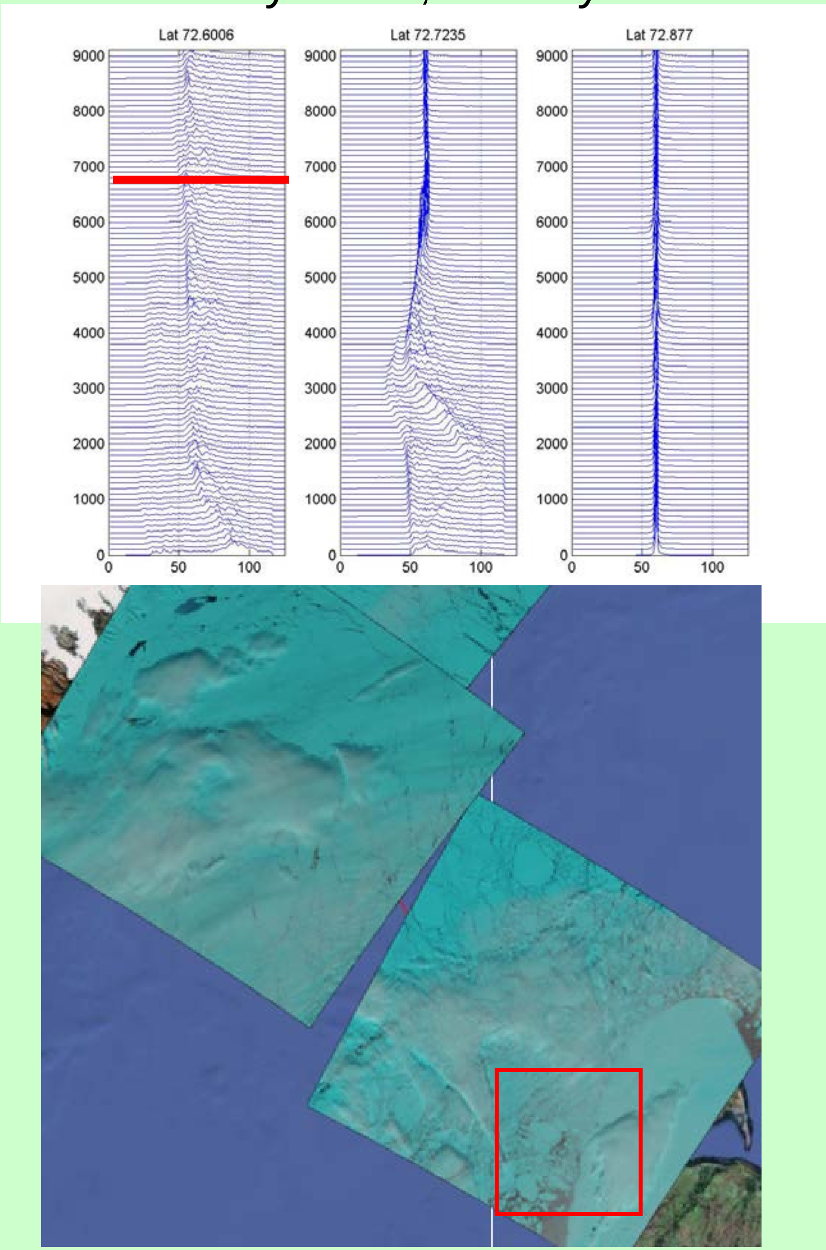


cycle 3, melting

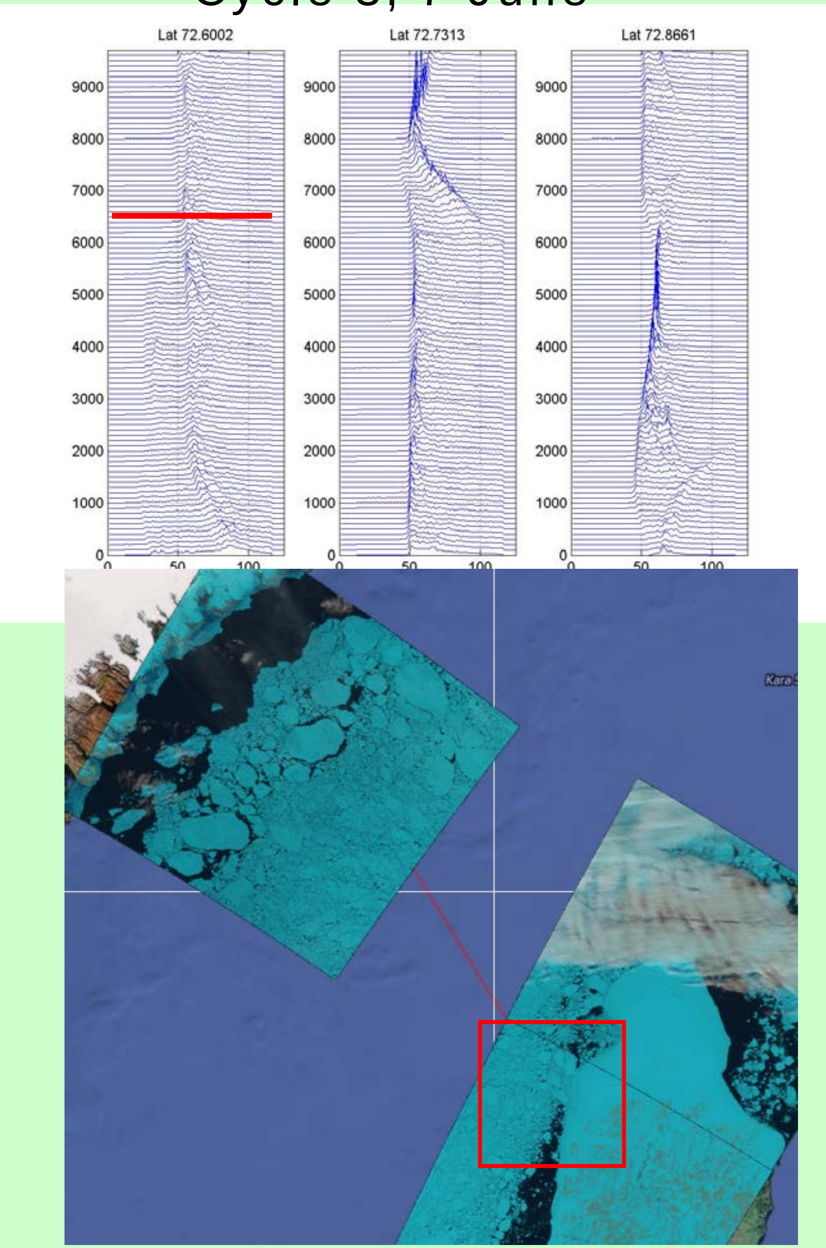


ALTIKA over Kara Sea : waveformes

Cycle 2, 1 May



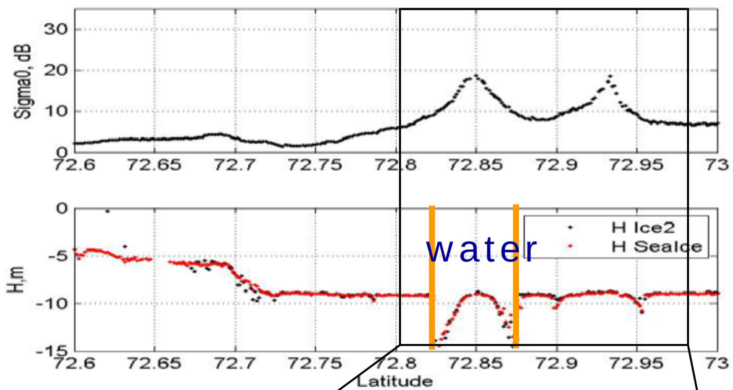
Cycle 3, 7 June

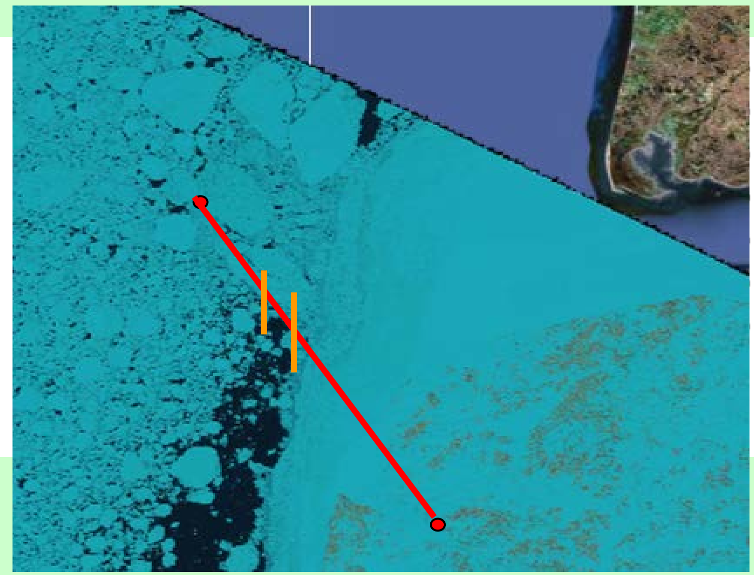


ALTIKA over Kara Sea: Sigma and Height

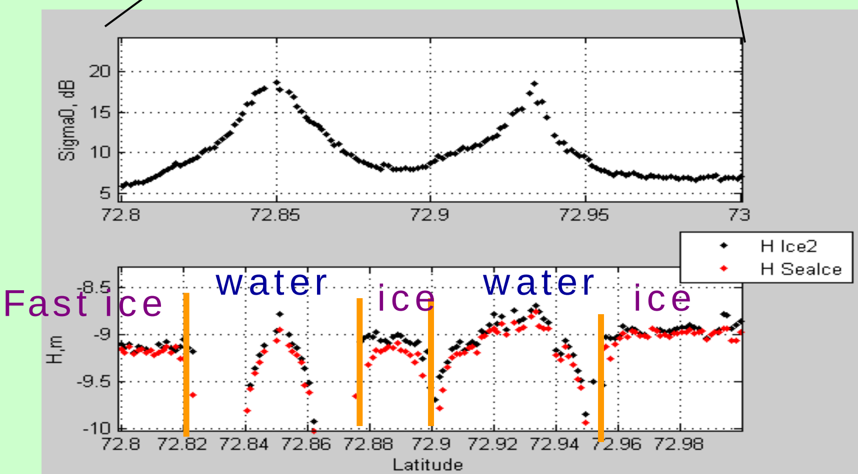
Cycle 3, 7 June

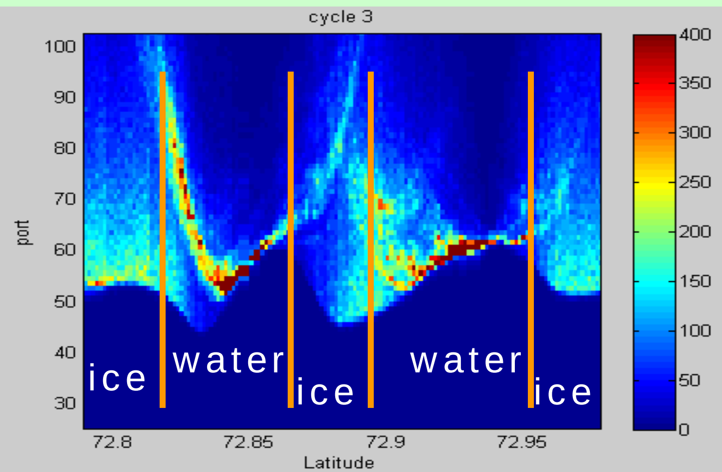
Landsat 8 June 2013





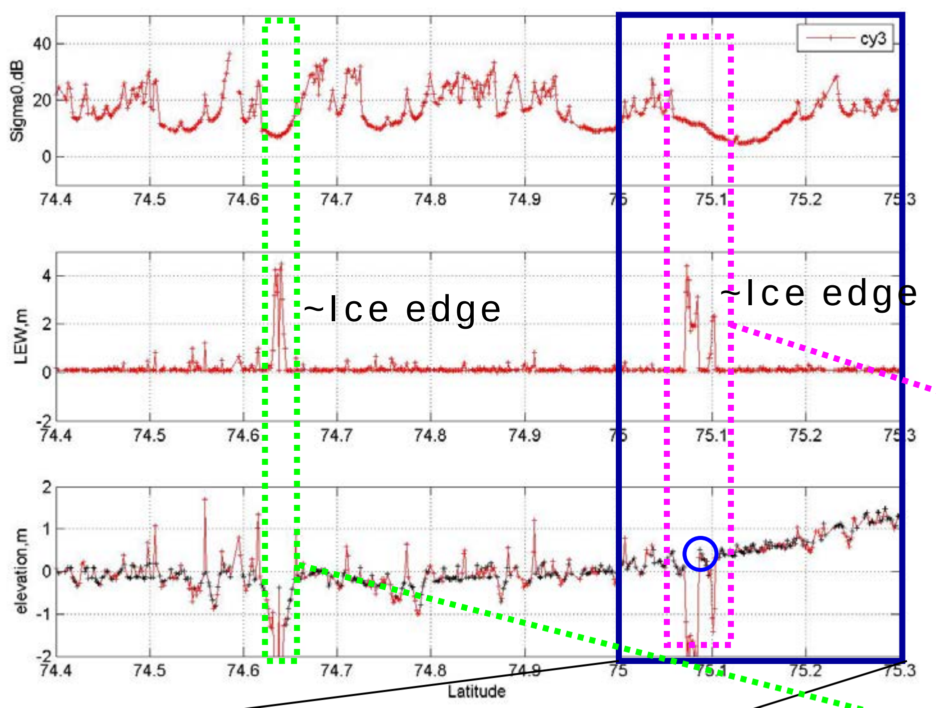
zoom





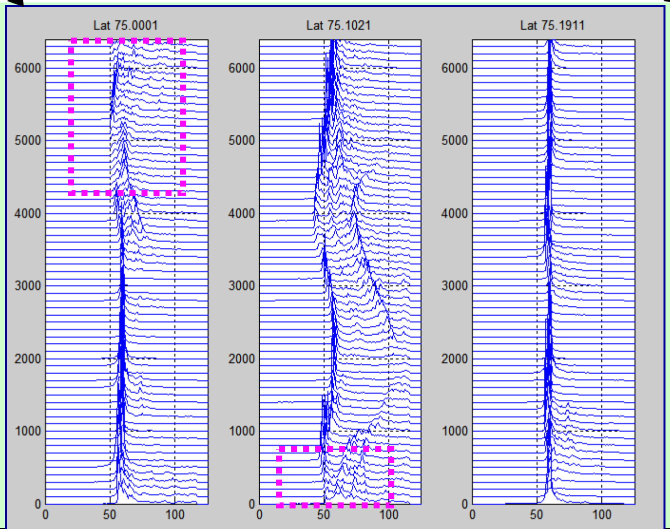
For height,
no geophysical corrections

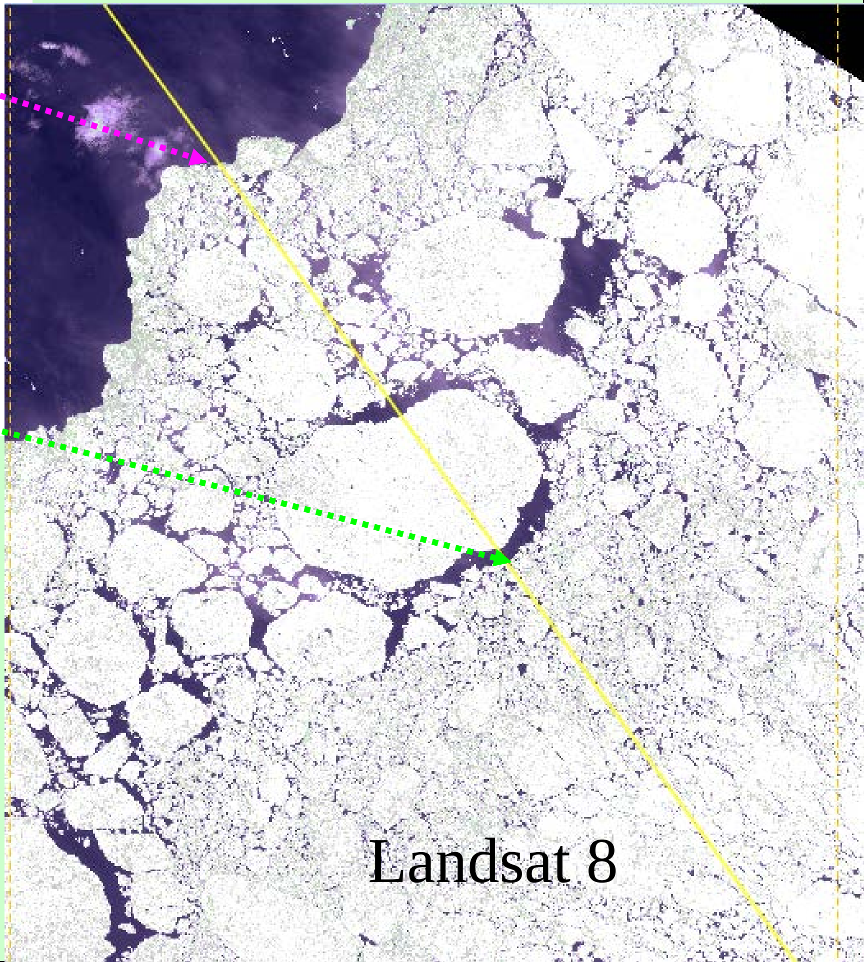
ALTIKA over Kara Sea: Sigma and Height



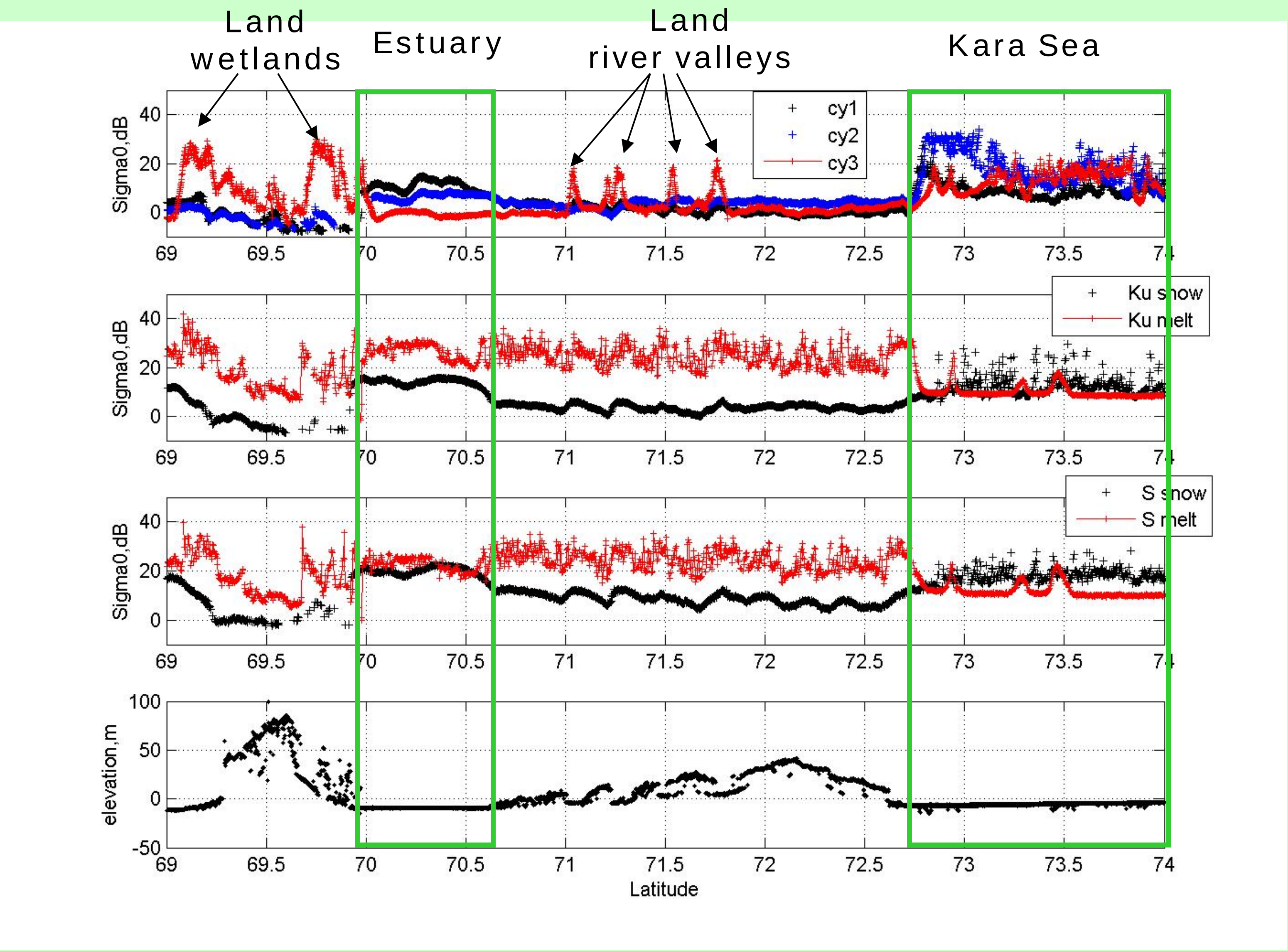
2 days timelag

Very dynamic ice fields:
difficult to accurately validate the ice extent





ALTIKA - ENVISAT over estuary and Kara sea



ENVISAT 2007