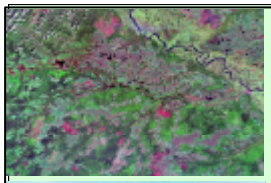
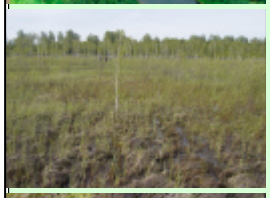




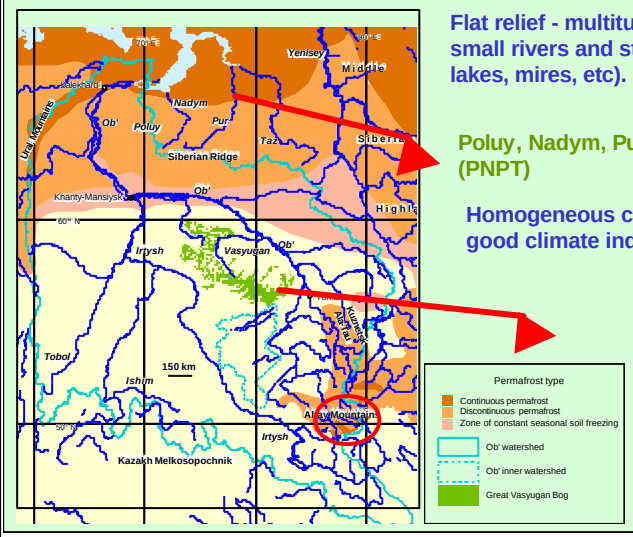
COSPAR Capacity Building Workshop
and WMO Training Course
on satellite remote sensing and climate change
Tver, Russia, 25 July 2014

Satellite monitoring and in situ observations for study of Siberian wetlands and rivers

Kouraev A.V., Zakharova E.A.,
Garestier F., Rémy F., Kirpotin S.N.,
Vorobyev S.N., Berezin A.Ye

Western Siberia: an unique region

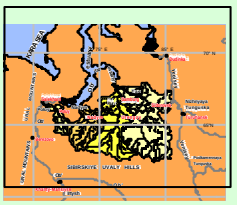
Ob' + Yenisey+ PNPT : 1250 km3 /year (greatest input among all other Arctic seas)



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

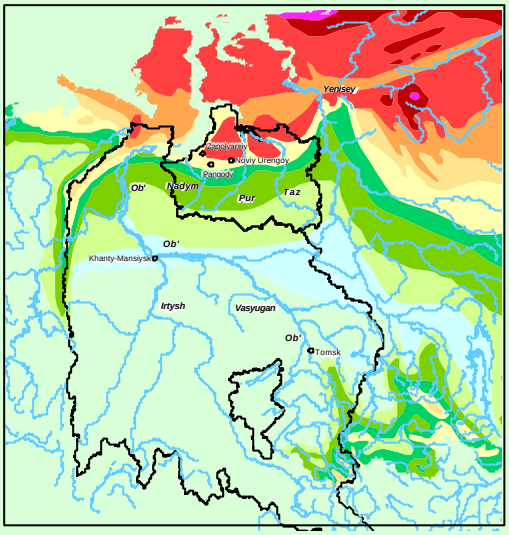
World's largest peatland (6.78 million ha). Appeared 10 000 years ago and constantly growing. 75% of the actual surface appeared during the last 500 years.

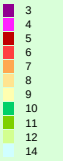
Permafrost conditions

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

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 !

Context: active national/international cooperation

Cooperation CNRS-Russia: GDRI CAR-WET-SIB (Biogeochemical cycle of carbon in wetlands of Western Siberia)

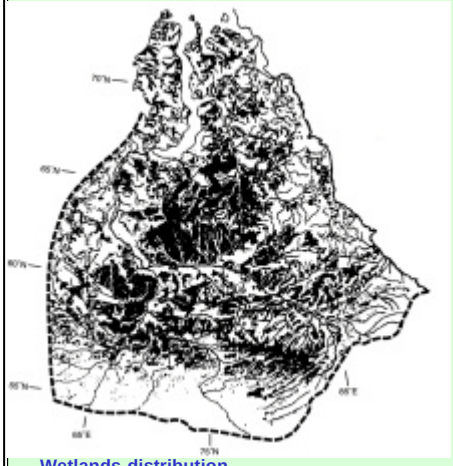
French ANR Projects "Impact-BOREAL", "CLASSIQUE"

FP7 "MONARCH-A"

Field studies in the Noviy Urengoy region (summers of 2008-2010), Altai mountains (summer 2009), snow survey over Western Siberia (2011)

Int. J. of Environmental Studies August 2009 - special issue on Western Siberia with several our publications on this subject

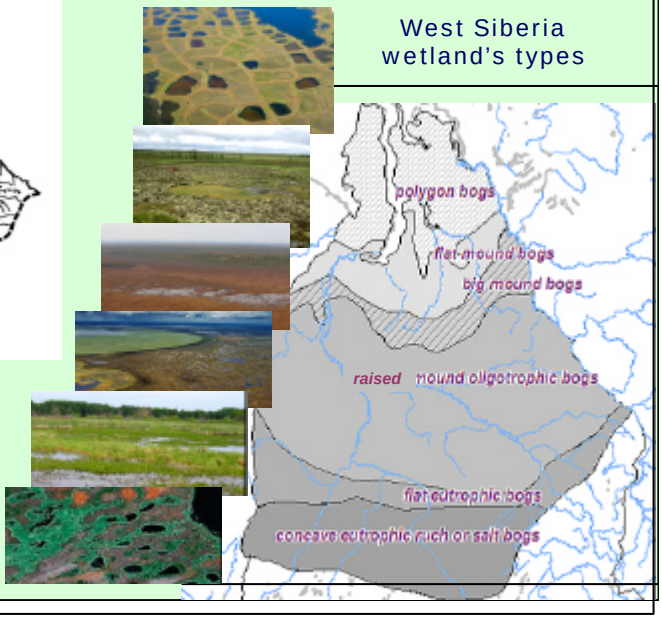
1. Wet zones extent



Wetlands distribution
(after Ivanov and Novikov, 1976)

Water storage in interfluvial wetlands

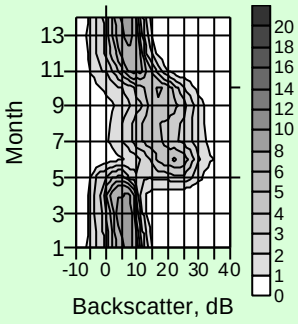
West Siberia
wetland's types



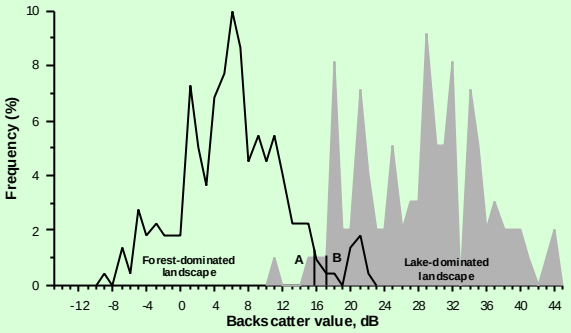
Different morphology and water regime

ENVISAT 18 Hz backscatter values in Ku-band (Ice2 retracker) for 2002-2010

Altimetry: threshold?



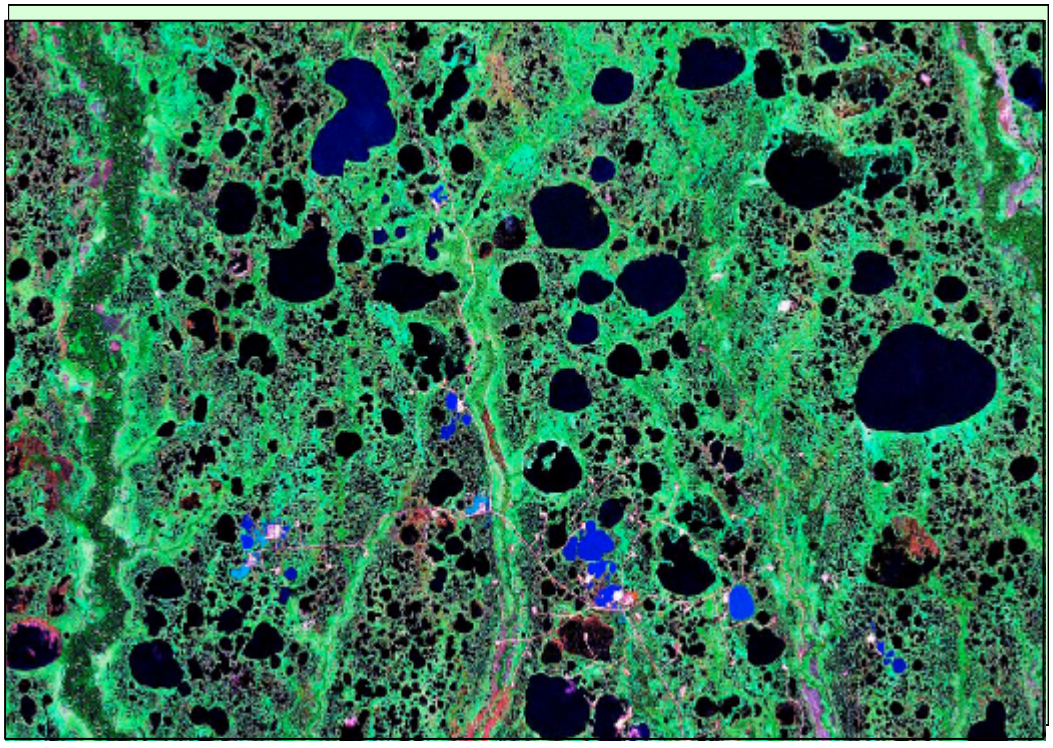
Seasonal probability distribution for the Taz watershed



Frequency (%) histograms of backscatter values (June-August) for forest- and lake-dominated landscapes.

17 dB

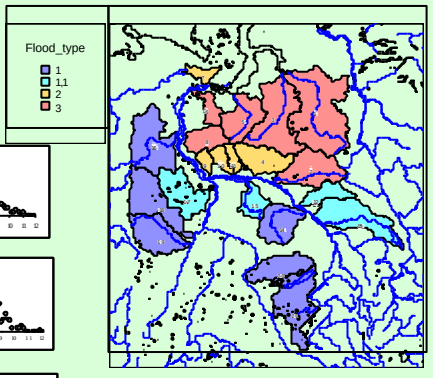
Zakharova et al., J. of Hydrology, 2014



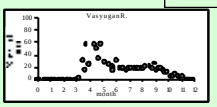
What do we see from backscatter in Siberia?

21 watersheds

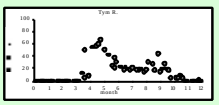
Using ENVISAT data we estimate the extent (%) of wet zones within 21 mid-size watershed of the Ob' river system. Basing on the difference in seasonal signal we grouped the watersheds into the 3 main types (and one subtype)



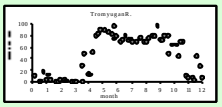
Type 1: Small permanent flooding (one peak) and well pronounced draining



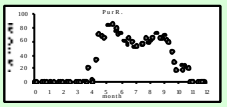
Type 1a: Same as 1 but with two peaks



Type 2: High permanent flooding with insignificant draining



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

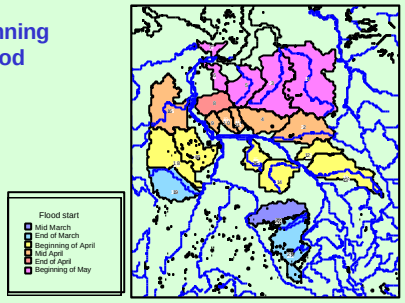


No	River name
1	Taz
2	Vakh
3	Pur
4	Trom Yugan
5	Nadym
6	Poluy
7	Schuchya
8	Kazym
9	Nazym
10	Lyamin
11	Pim
12	Tym
13	Ket
14	Vasyugan
15	Big Yugan
16	Severnaya Sosva
17	Konda
18	Tavda
19	Tura
20	Om
21	Inner watershed

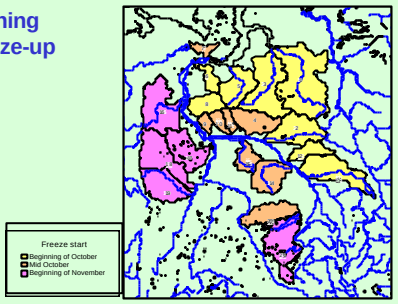
Zakharova et al., J. of Hydrology, 2014 (under revision)

Wet zones: timing of seasonal variations

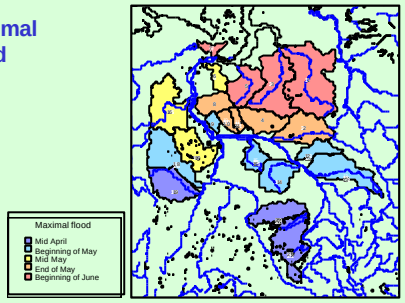
Beginning of flood



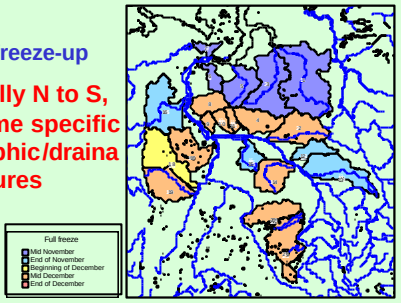
Beginning of freeze-up



Maximal flood



Full freeze-up

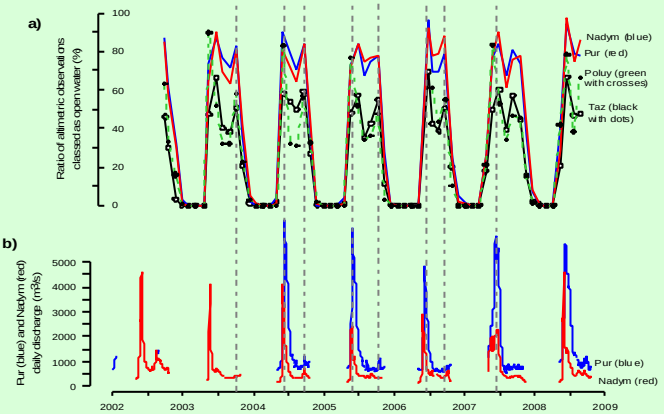


Generally N to S, but some specific orographic/drainage features

Wet zones: interannuall variations

Wet zones extent (%) (PNPT)

Discharge (NP)

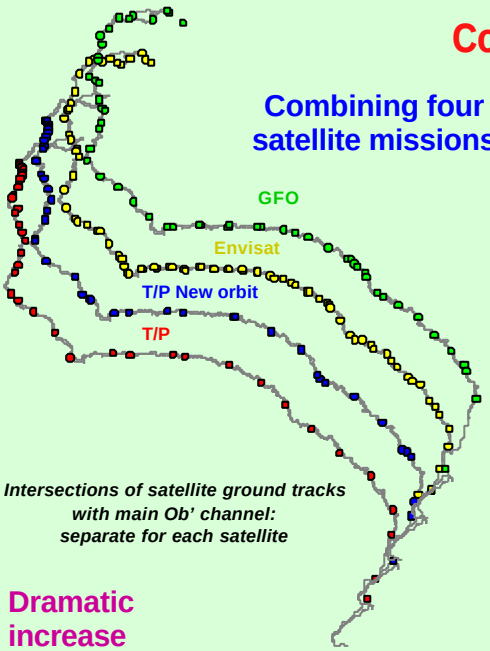


Significant variability from year to year.
Wet zones extent (%) similar in spring and autumn, though in volume it is very different
=> need to study water level changes

2. Water level

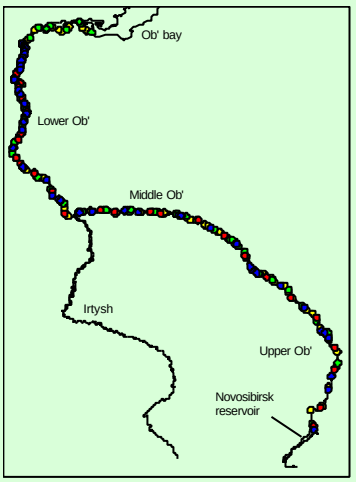
Coverage by four satellites

Combining four satellite missions



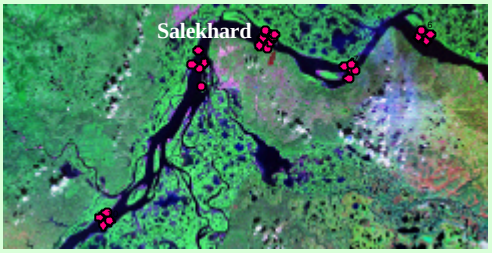
Intersections of satellite ground tracks with main Ob' channel: separate for each satellite

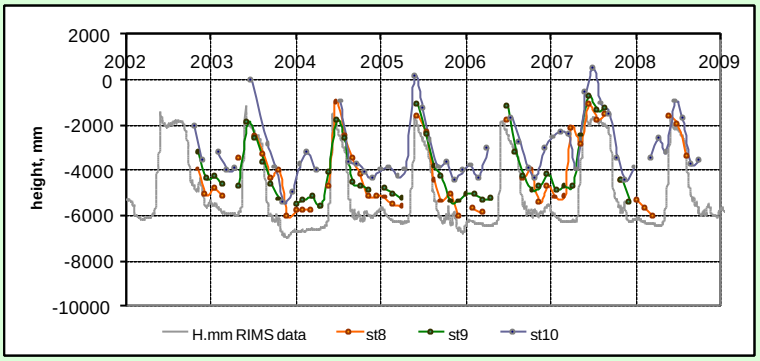
Dramatic increase of spatial coverage

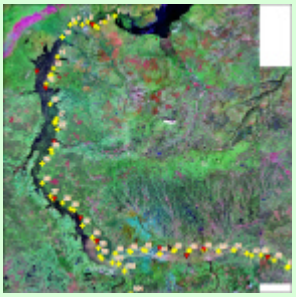


Intersections of satellite ground tracks with main Ob' channel: all four satellites

Ob River : water level validation





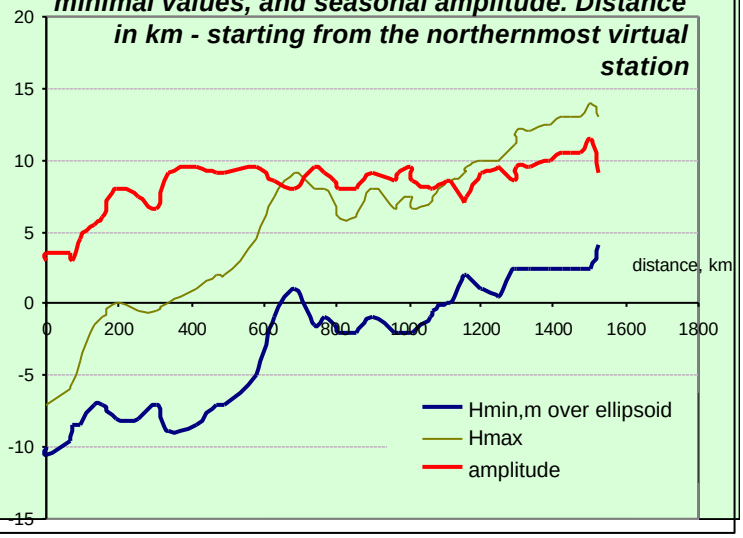


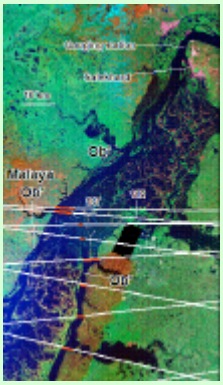
Input to the preparation of AltiKa satellite altimetry mission

58 virtual stations

Water level variability: Ob ' river

Water level (m, over ellipsoid): maximal and minimal values, and seasonal amplitude. Distance in km - starting from the northernmost virtual station

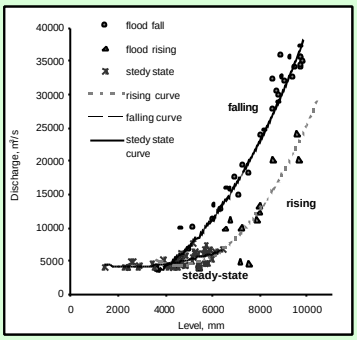




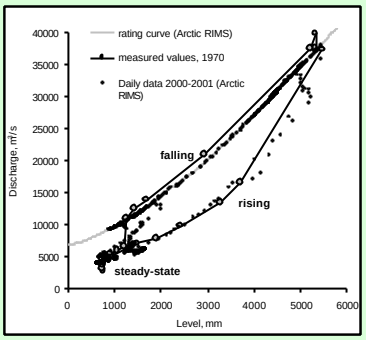
Ob' : level and discharge relation

Establish direct relation H(T/P) - Q at Salekhard

Sat Alti vs in situ



In situ vs in situ



Three periods:

Flood rising, flood falling, quasi-steady

H-Q relation as a function of the hydrological phases: (a) – T/P data, (b) - in situ data (1970 and 2001)

Ob' discharge by satellite altimetry

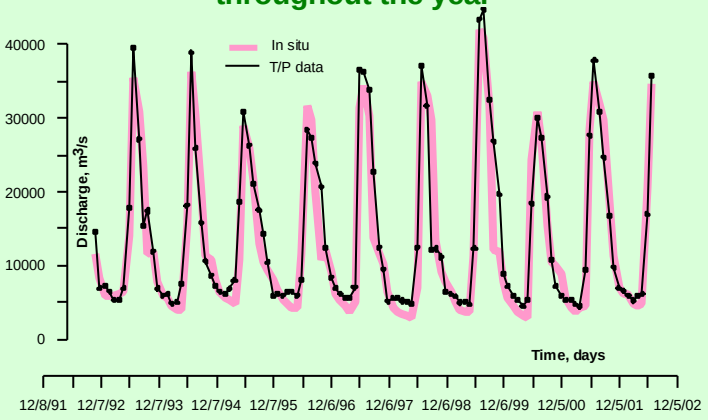
Winter: noise in H do not affect Q

Estimated errors in T/P Q:

5% for annual data

15% for mean monthly data

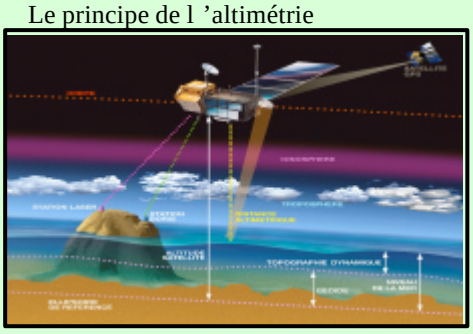
Good relation of two series throughout the year



Mean monthly water flow (m3/s) at Salekhard from in situ and satellite-derived data (track 187)

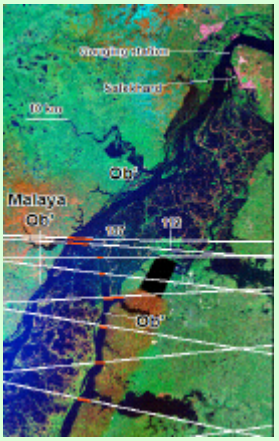
[Kouraev et al., Remote Sens. Environ., 2004]

Le principe de l ’altimétrie

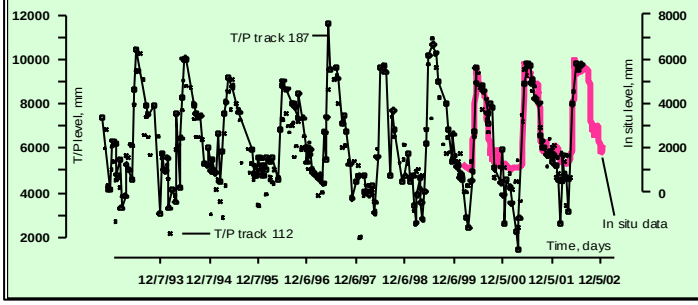


Observation du niveau d ’eau par altimétrie satellitaire

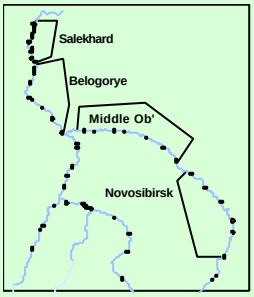
Landsat TM image of Lower Ob’, T/P tracks (white) and selected sections (red)



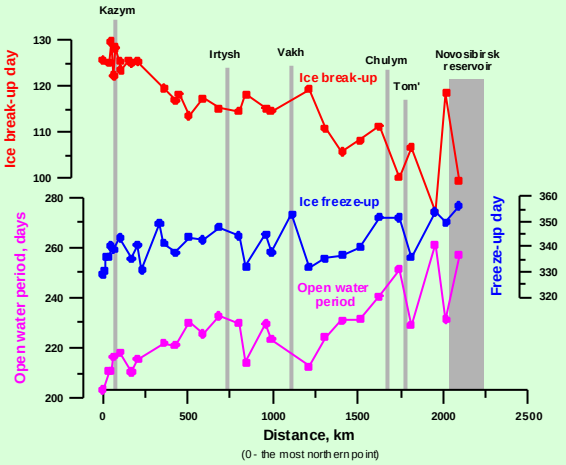
River level from in situ observations at Salekhard and TOPEX/Poseidon data



Bassin de l ’Ob

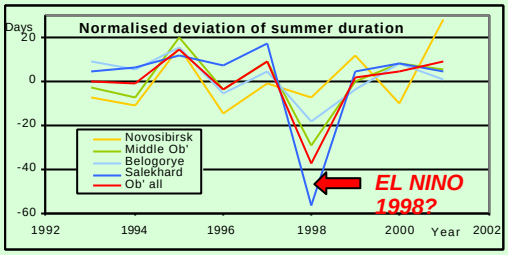


Regime de la glace par l’altimetrie

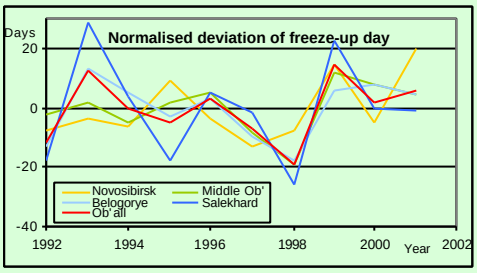


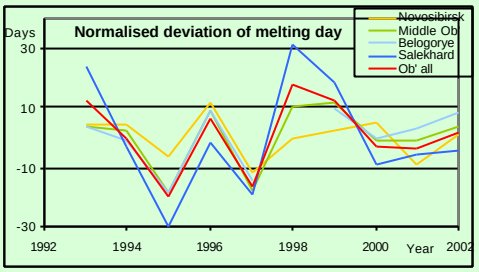
Ice break-up and freeze-up day and duration of open water period along the main Ob’ channel (Topex/Poseidon data)

Regime de la glace par l'altimetrie



Grande variation interannuelle des événements glacials





Embâcles (ice jams)

Les rivieres boréales : la cru propage du Sud au Nord

Les embâcles se forment en méandres, en confluences

Extrêmes nivaux d 'eaux

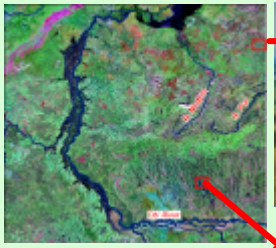
La destruction de la glace par les forces mécaniques

bombardement

Les dégât sont énormes

Two regions

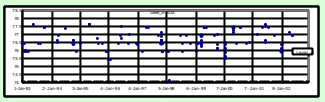
Nadym region



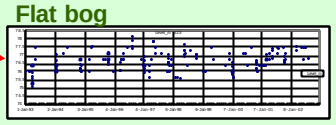
Surgut region

Water level

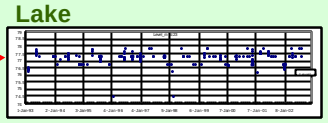
Lake



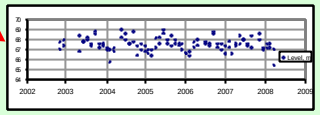
Flat bog



Lake



Draned lake

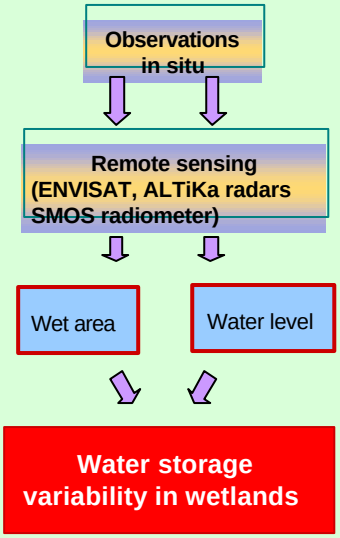


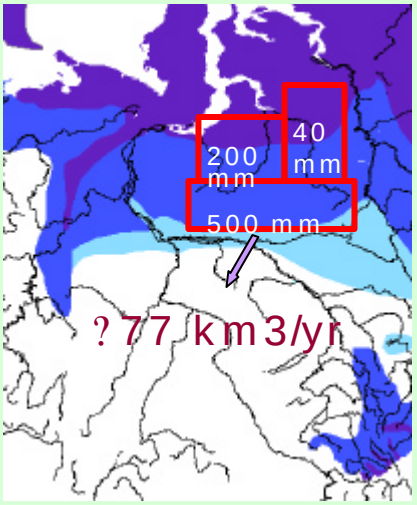
Variability is highest (1-1.5 m) for lakes, much less (50-70 cm) for flat mires and drained lakes.

Wetlands have regulating (dampening) affect on water level

Water storage in interfluvial wetlands

Seasonal variability of water storage

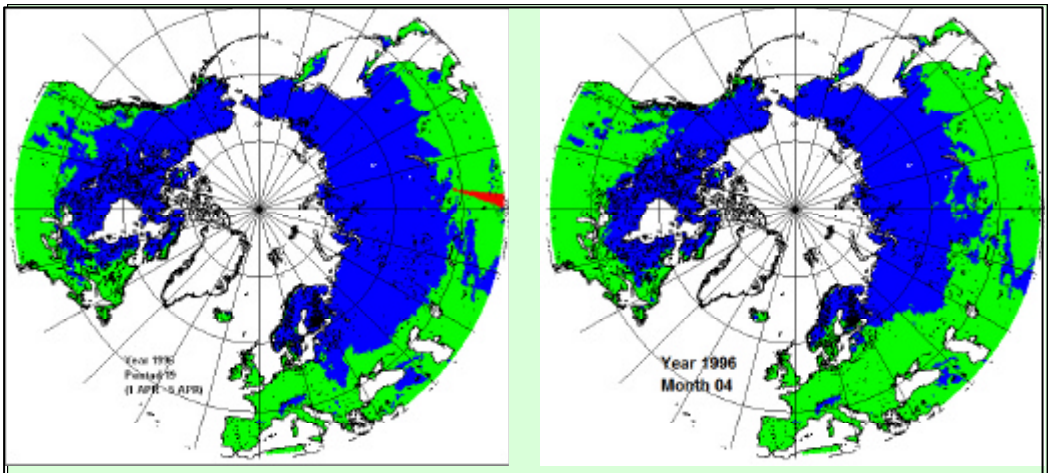




Zakharova et al., J. of Hydrology, 2014

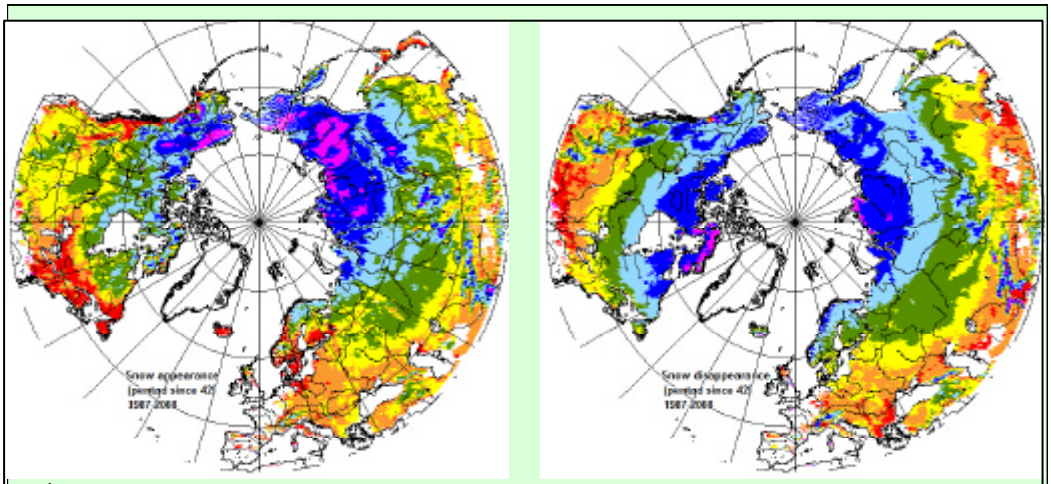
3. Discharge and its relation with snow cover

Snow cover from satellite radiometers



Snow extent for pentad 19 (1-5 April) of 1996 (left) and April 1996 (right).

Green color - land, blue - snow, red - no data, white - ocean/excluded pixels.

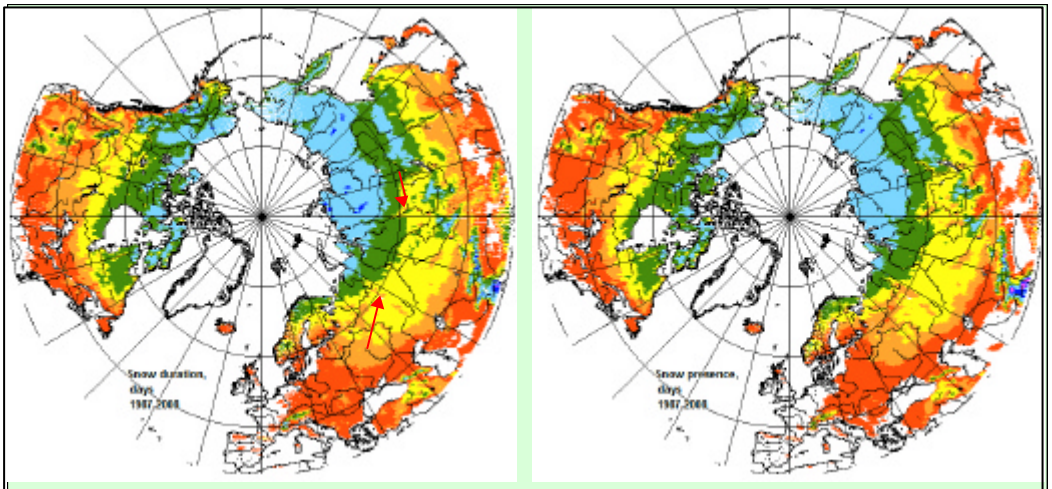


Appearance pentad (dates)
- 1-15 (31 Jul - 9 Oct)
- 15-20 (9 Oct - 3 Nov)
- 20-25 (3 Nov - 28 Nov)
- 25-30 (28 Nov - 23 Dec)
- 30-35 (23 Dec - 17 Jan)
- 35-40 (17 Jan -11 Feb)
- 40-73 (11 Feb - 29 Jul)

Average (1987-2008) dates (in pentads since pentad 42, July 29) of snow appearance (left) and disappearance (right)

Condition - three consecutive pentads of snow/no snow

Disappearance pentad (dates)
- 65-73 (16 Jun - 29 Jul)
- 60-65 (22 May - 16 Jun)
- 55-60 (27 Apr - 22 May)
- 50-55 (2 Apr - 27 Apr)
- 45-50 (8 Mar - 2 Apr)
- 40-45 (14 Feb - 8 Mar)
- 1-40 (31 Jul - 14 Feb)



Duration/Presence (days)
- 300-365
- 250-300
- 200-250
- 150-200
- 100-150
- 50-100
- 1-50

Average (1987-2008) snow duration (difference between start and end date), left, and total snow presence (number of days when snow was present (right) (days)

Some influence of topography (Urals, Yenisey etc)

Field trip - snow survey, 8-17 March 2011

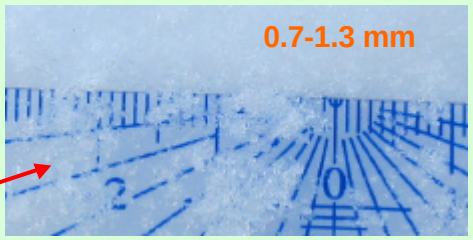
1700 km transect Novosibirsk - Purpe

Monarch-A/CAR-WET-SIB cooperation with Institute of Soil Sciences (Novosibirsk)

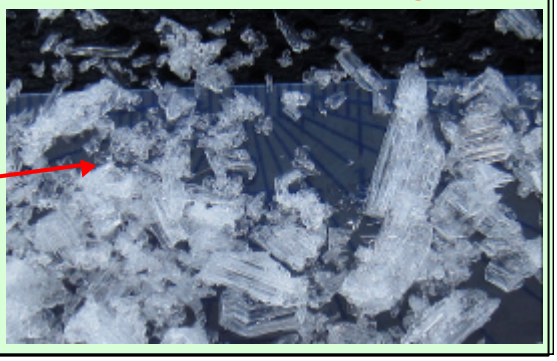
Snow depth, snow density, vertical profiles, grain size, snow and water samples

Snow grain size

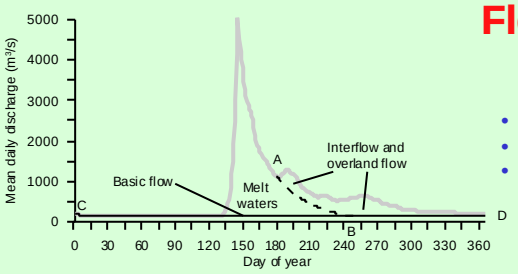
0.7-1.3 mm



2-15 mm



Flow components estimates



Data on daily discharges are used for the estimates of the flow components parts

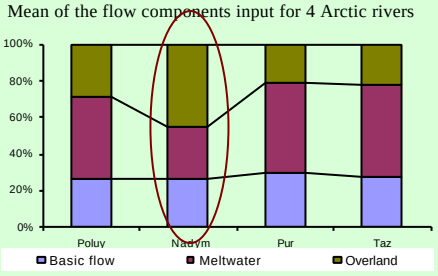
Three main sources of water flow :

- **melt waters**
- **ground waters (basic flow)**
- **rain waters (interflow and overland flow during ice free period)**

Nadym river: low impact of melt water (29%) and high impact of overland/interflow (45%)

Changes in a watershed properties as a result of intense human impact related with gas exploration

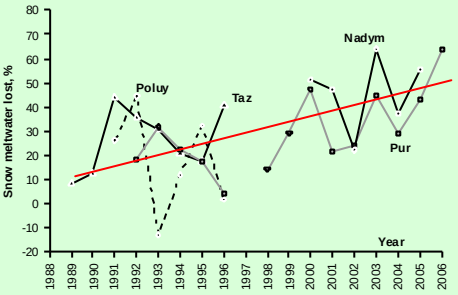
Mean of the flow components input for 4 Arctic rivers



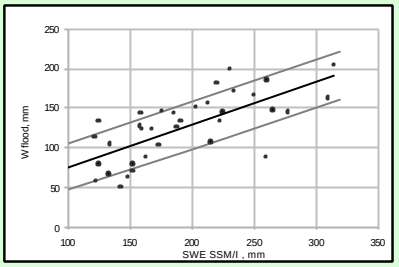
Snow cover and flood flow

Estimation of spring flood volume (using in situ daily data on discharge and hydrograph graphical separation) - Zakharova et al., IJES 2009

Very good relation => possibility to quantify role of snow in seasonal water redistribution



Temporal evolution of difference between snow volume and spring flood (I.e. % of snow lost)

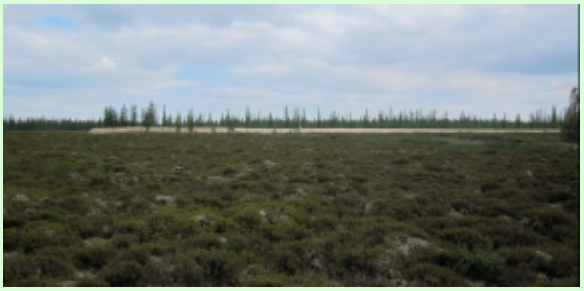


Snow water equivalent from SSM/I and in situ data versus spring flood volume

However we lose about 20-60% of snowmelt water for evaporation + retention for later release

The ratio of water lost is increasing for PNPT - climate change or anthropogenic impact?

Zakharova et al., J. of Hydrometeorology, 2011

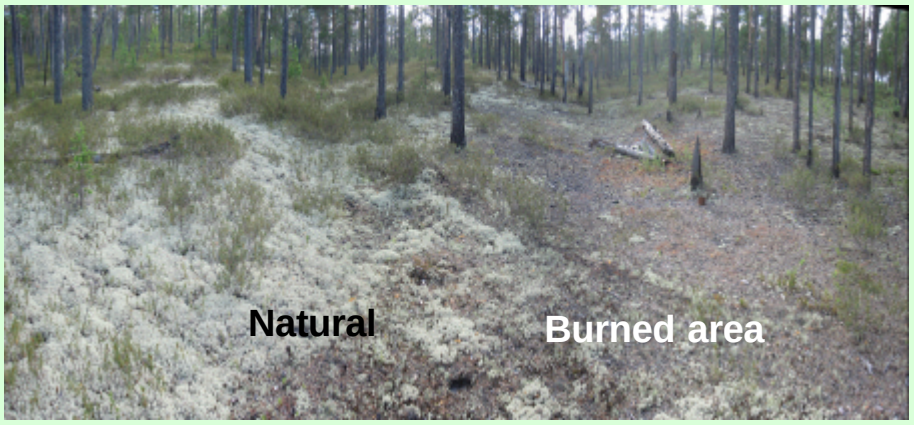


New road to gas wells

Human activity is blocking natural flow, creating new lakes, wet zones upstream and dry zones downstream

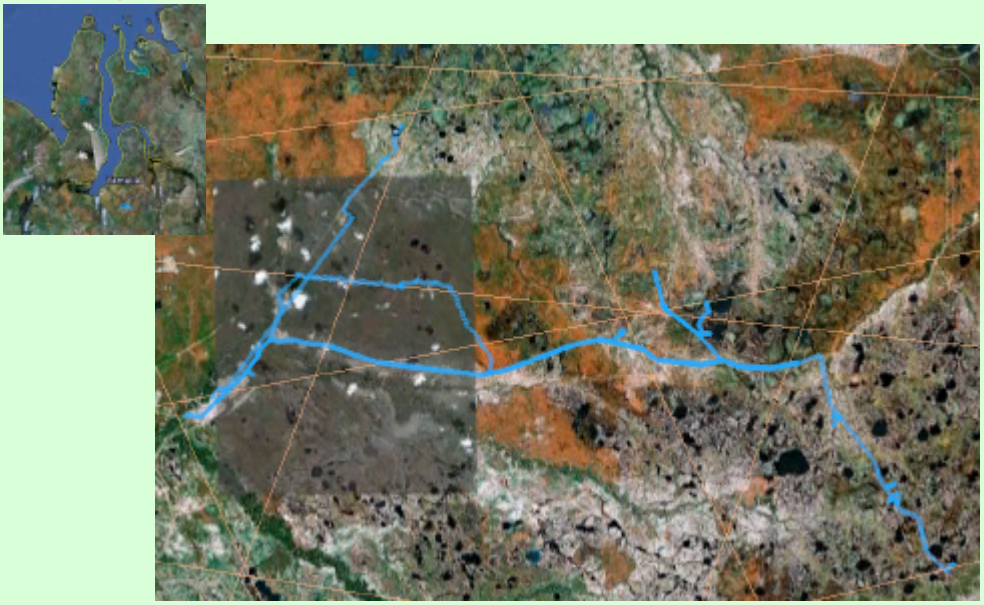
Road and gas pipeline over river and over land

Impact of fires on lichens: increased albedo => affecting active layer depth



4. Soil moisture: satellite and in situ data

Field measurements: Noviy Urengoy - Pangody August 2010



Water quality (pH, EC, O_2), samples

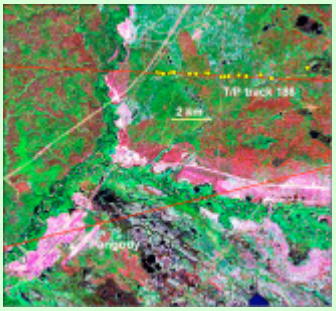
Ultra-fast transport

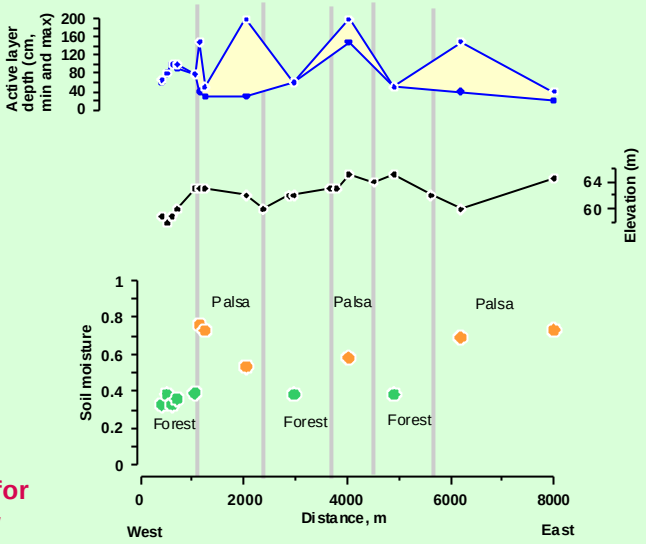
Active layer depth

Soil moisture

Soil samples

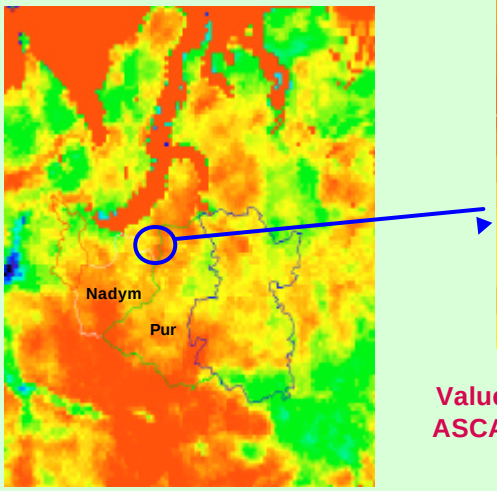
Pangody: in situ soil moisture and active layer depth along the transect (9 Aug 2010)

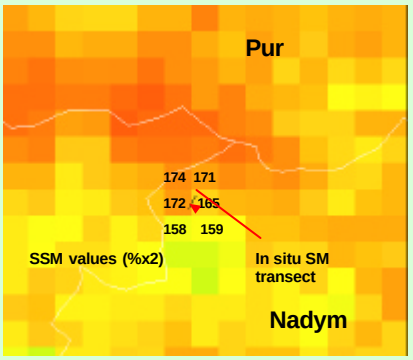




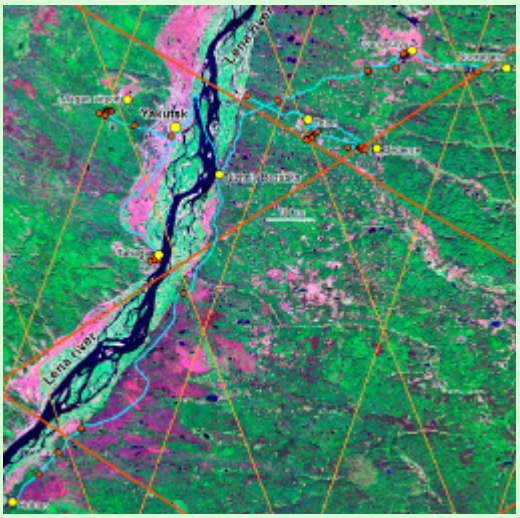
In situ: low SM values for forest (30-40%), high for palsa (50-80%). ALD: Low values but large changes for palsa, high values and low changes for forest

STSE ALANIS SSM product from METOP ASCAT (9-15 Aug 2010)



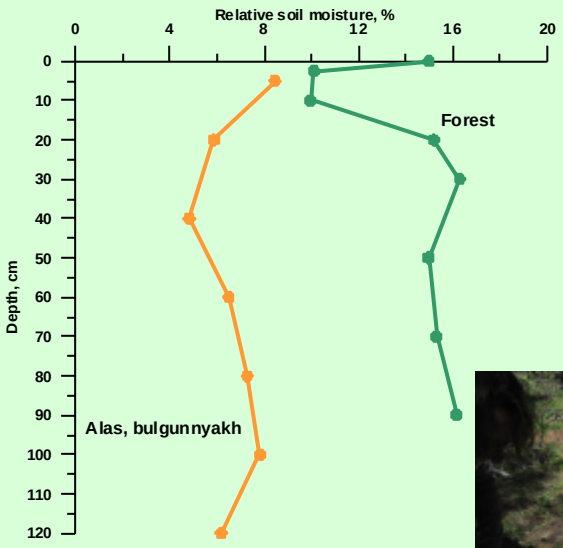


Values for transect are 86-82.5%. ASCAT too high (?), in situ varies from 30 to 50 (80)%



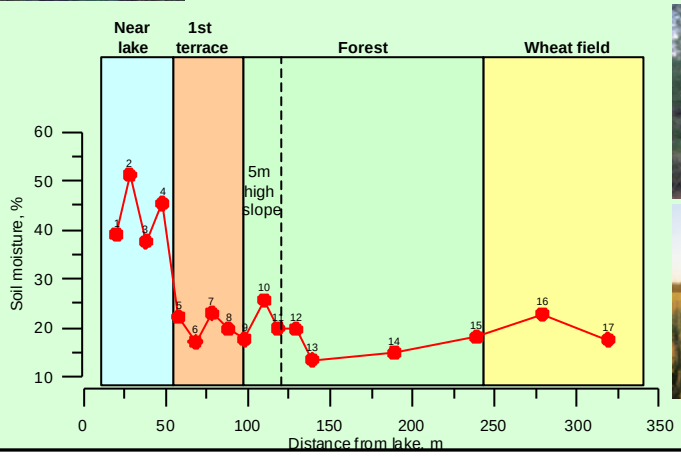
Yakutsk July 2012

Joint field trip with Melnikov Permafrost Institute SB RAS and Institute of Biological problems of Cryolithozone SB RAS

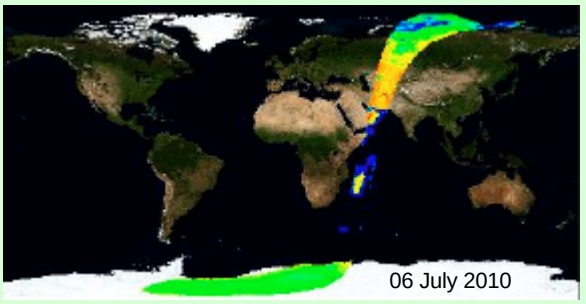


Vertical S&M profiles

Horizontal S&M profiles



SMOS: Soil Moisture and Ocean Salinity



Launched: 2 November 2009

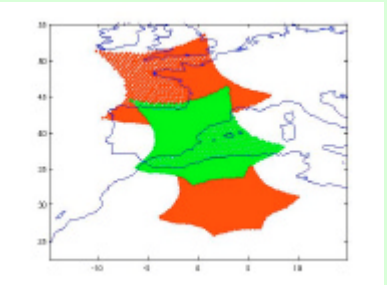
Instrument concept: Passive microwave 2D-interferometer

Frequency: L-band (1.4 GHz, 23 cm)

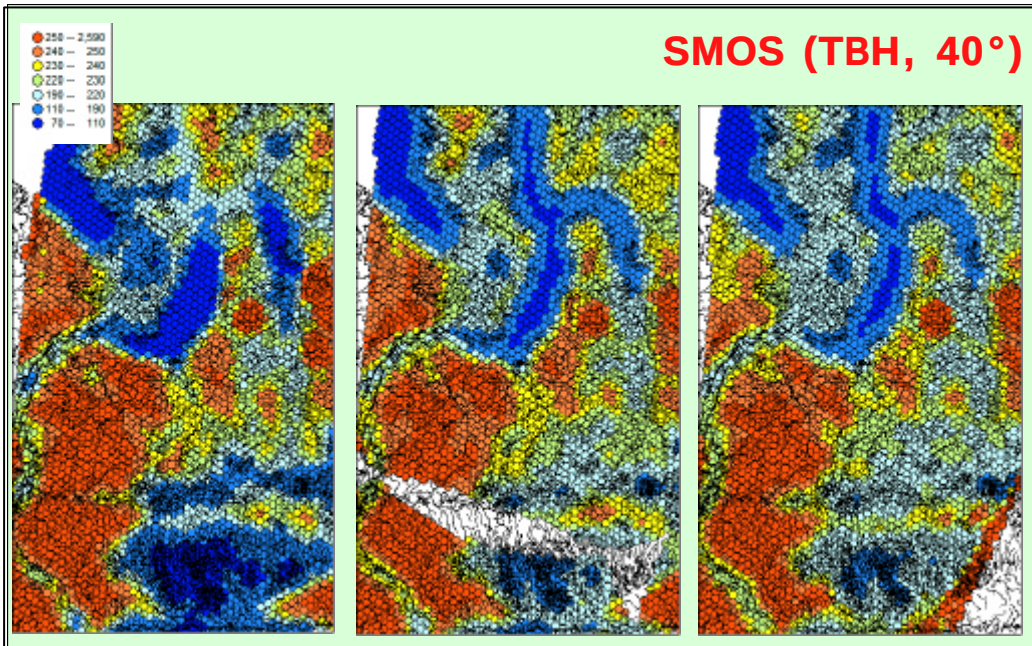
Spatial resolution: ~35 km

Global coverage every three days

First data - 12 January 2010

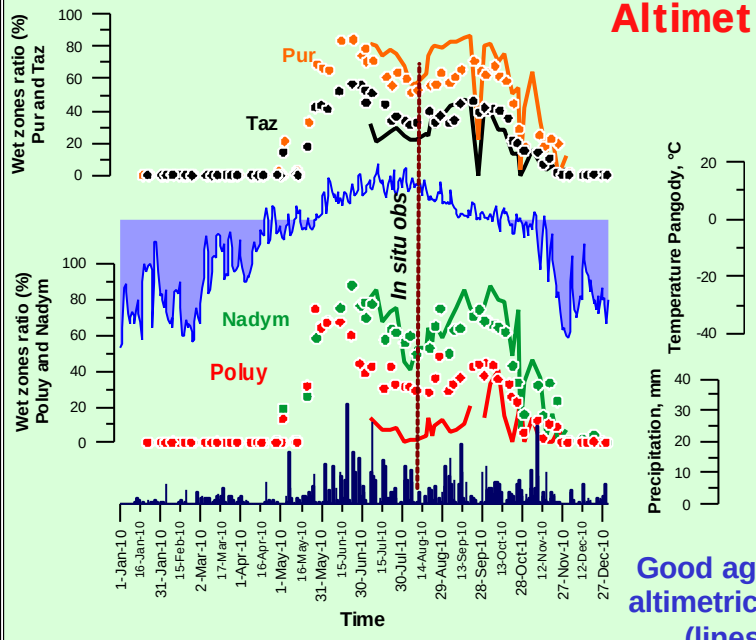


SMOS (TBH, 40°)



07 Jul 2010 | 21 Jul 2010 | 10 Aug 2010

Altimetry and SMOS



Good agreement between altimetric (dots) and SMOS (lines) estimates of wetzones (%)