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Satellite-derived data use for mitigating threats to water security

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COPUOS
2021

Water security: Data → Models → Understanding → Decisions

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Hydroinformatics: integration of data, models and decision making algorithms

Water security

The capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water

- for sustaining livelihoods, human well-being, and socio-economic development,

- for ensuring protection against water-borne pollution and water-related disasters, and

- for preserving ecosystems in a climate of peace and political stability."

(UNESCO-IHP, 2012. Final Report)

INDIRECT

- *Gaps in reliable hydrological information and data*
- *Poor integration of scientifically based instruments and decision making processes*
- *Insufficiently developed climate change adaptation and water management strategy*

Major threats to Water Security in Russia

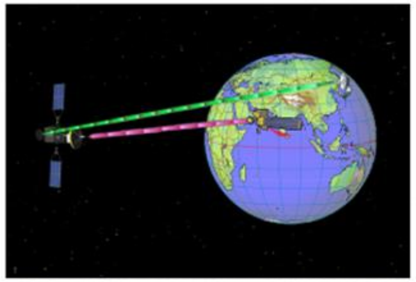
DIRECT

- *Floods*

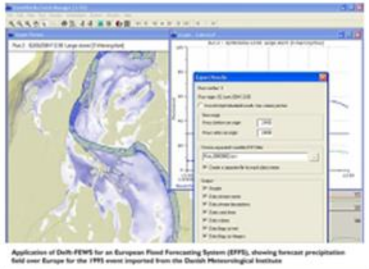
- *Water ecosystems deterioration and high risks of water pollution*

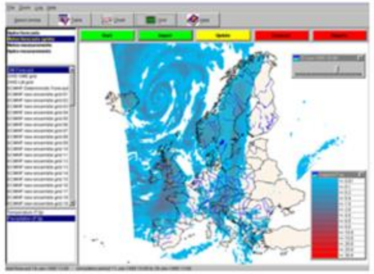
- *Clean water deficit*

In situ and remote measurements

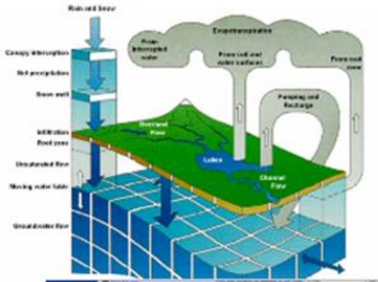


Numerical models of weather and climate





Integration with hydrological models, data assimilation



Decision making support

Flood risk management: direct observation and analysis of extreme hydrological events

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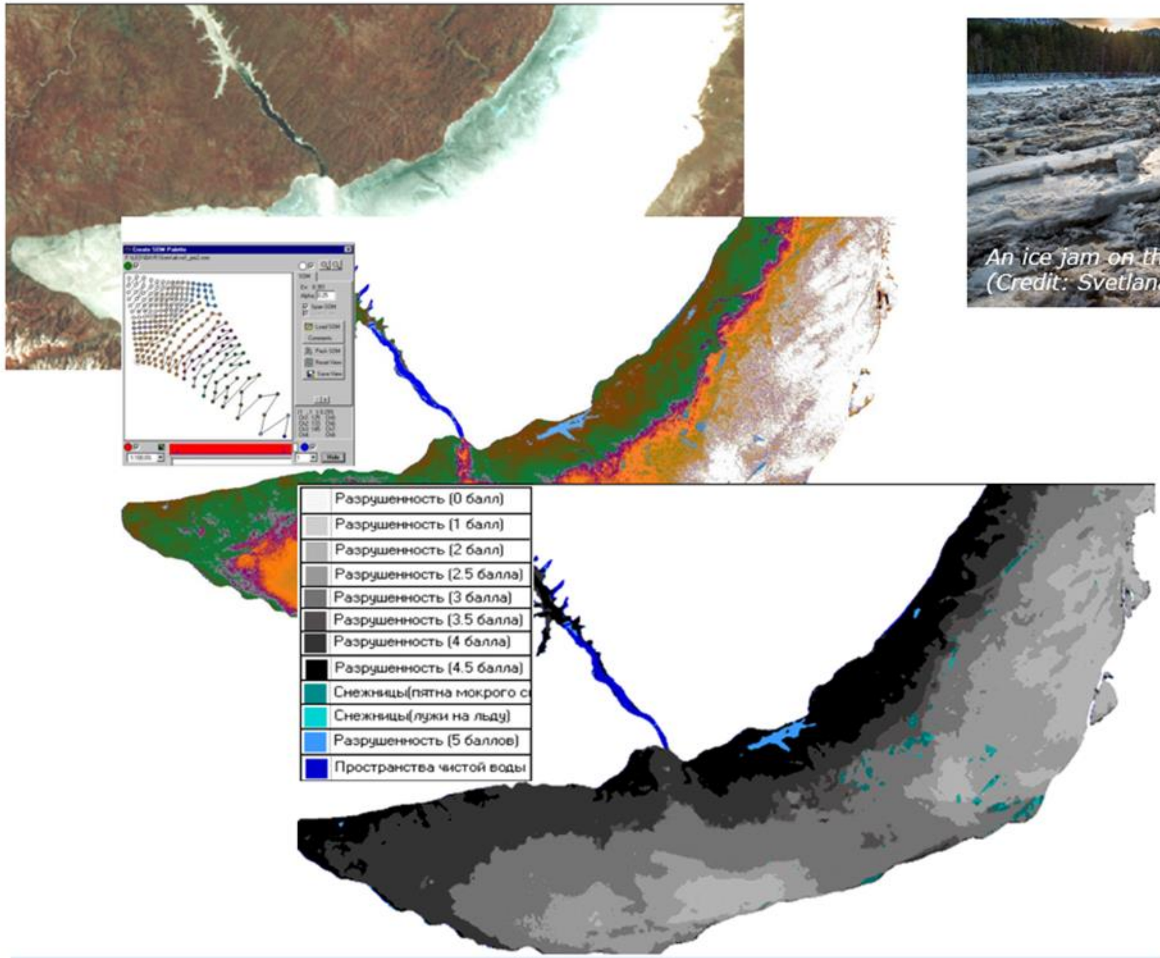
Three principal tasks in flood analysis based on remote data

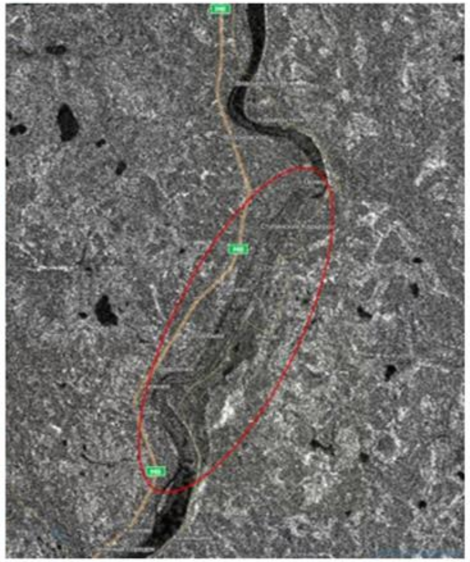
1 Snow storage and snow/ice melting rate monitoring

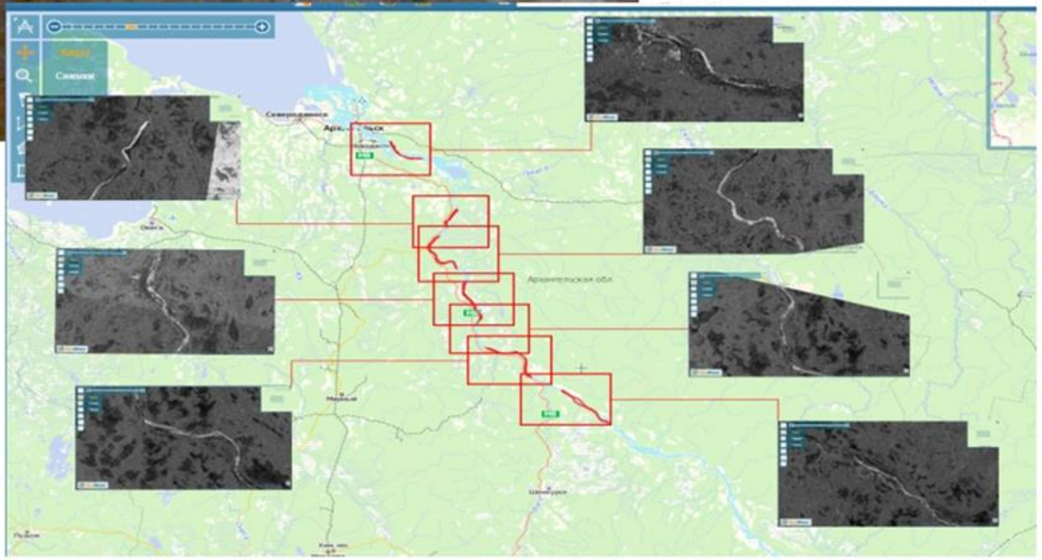


The different shades of colours over Lake Baikal and the Angara river surfaces indicate different states of ice cover from tough ice (pale grey) to "water above ice" (greenish) and open water (dark blue)

2 Ice jams identification


An ice jam on the Katun river (Credit: Svetlana Kazina)





A series of snapshots taken from a satellite facilitates analysing a spatial distribution of ice jams at a drainage basin scale of the Northern Dvina river (bottom)

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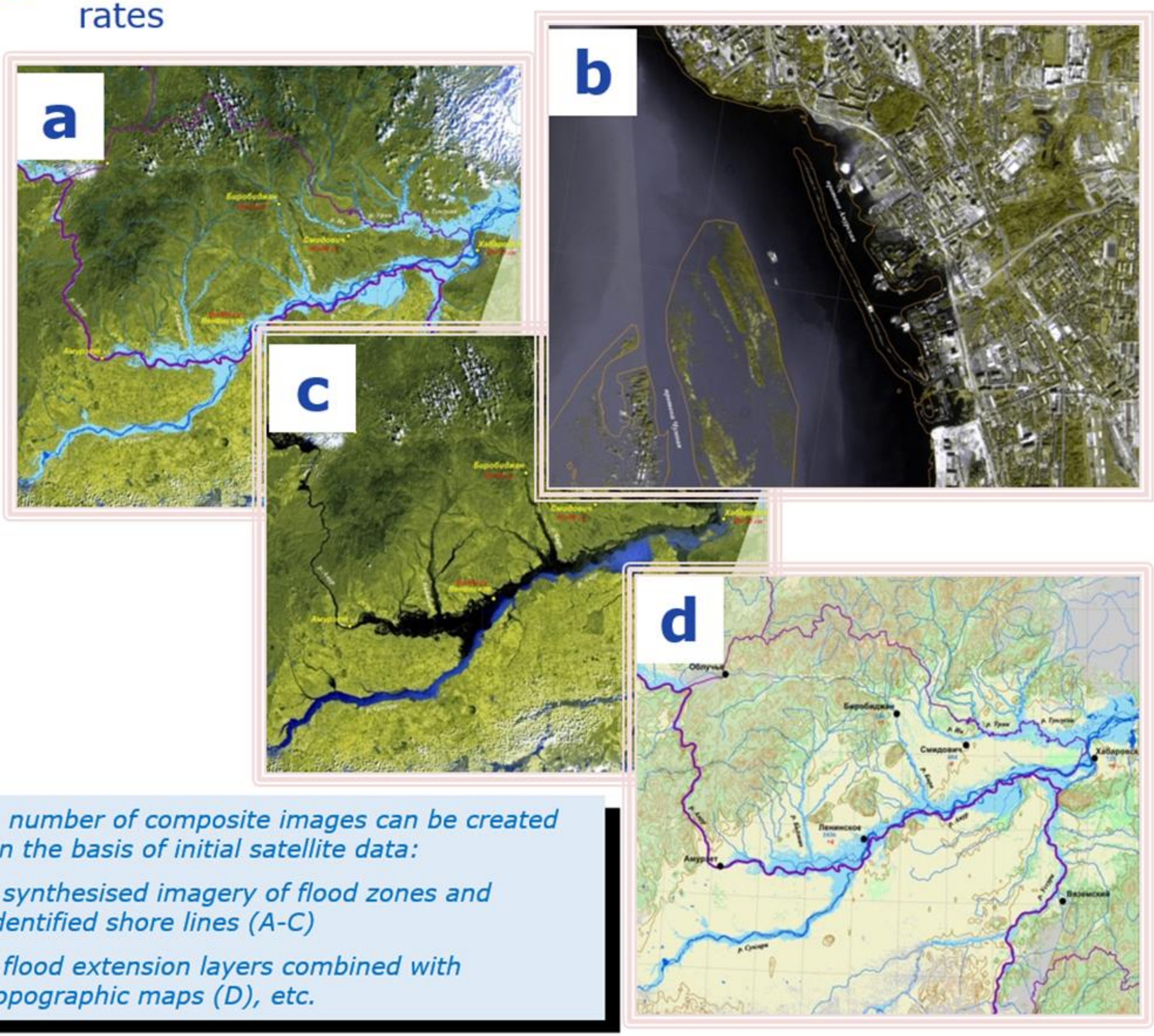
Flood risk management: direct observation and analysis of extreme hydrological events

Three principal tasks in flood analysis based on remote data

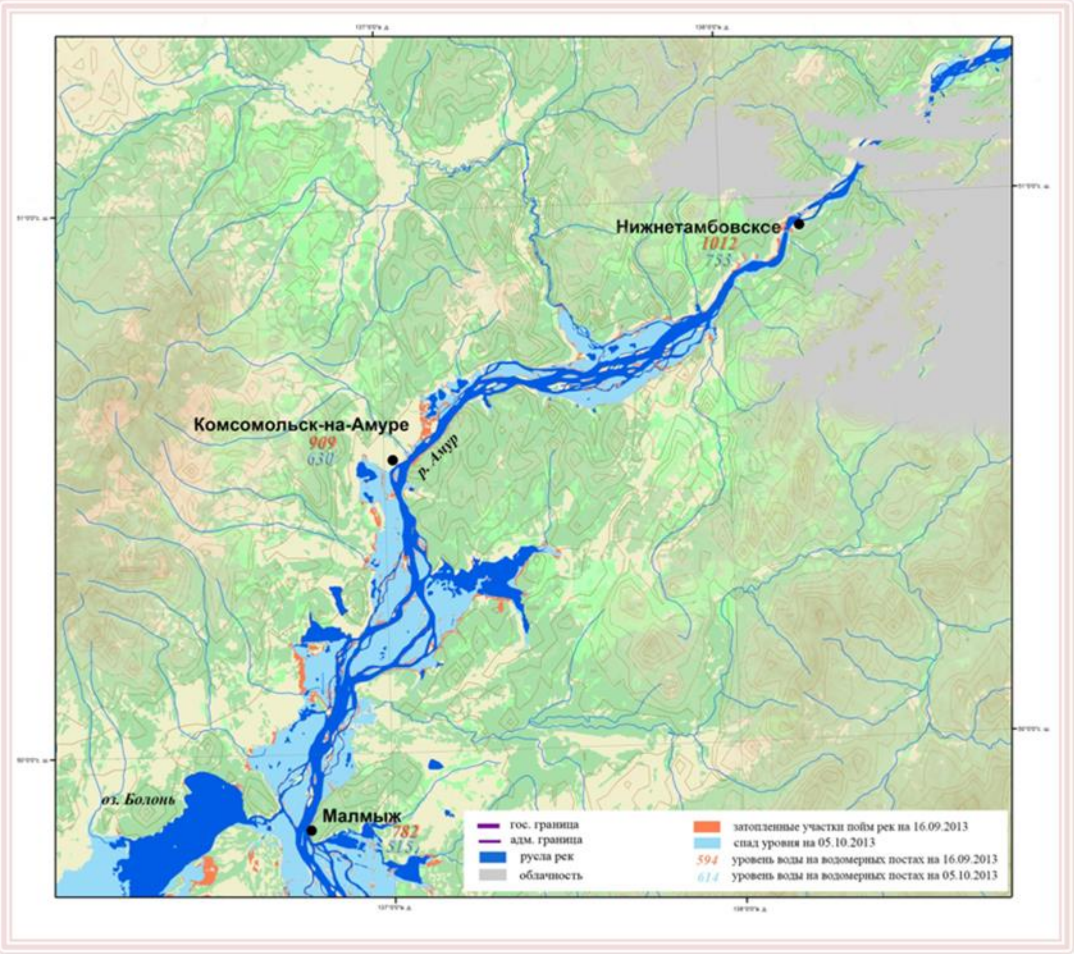
3 Monitoring of flood development rates



A number of composite images can be created on the basis of initial satellite data:

- synthesised imagery of flood zones and identified shore lines (A-C)

- flood extension layers combined with topographic maps (D), etc.



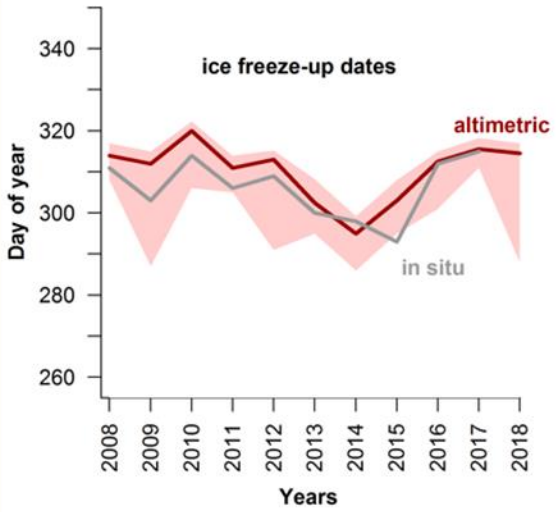
Two successive flood episodes during the Amur flood in 2013 with water extent on 16.09/2013 (orange) and 05.10/2013 (pale blue). The example of comparative analysis that allows to identify a spatial flood dynamics.

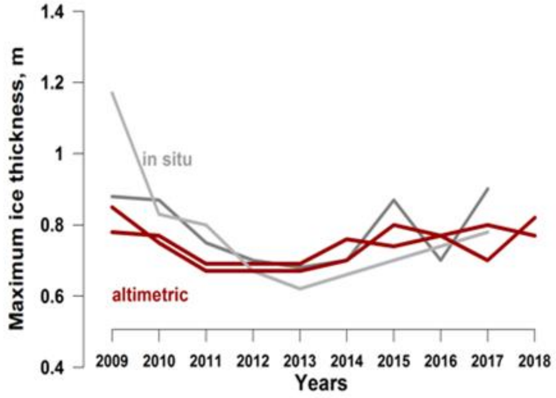
Ice regime monitoring applications

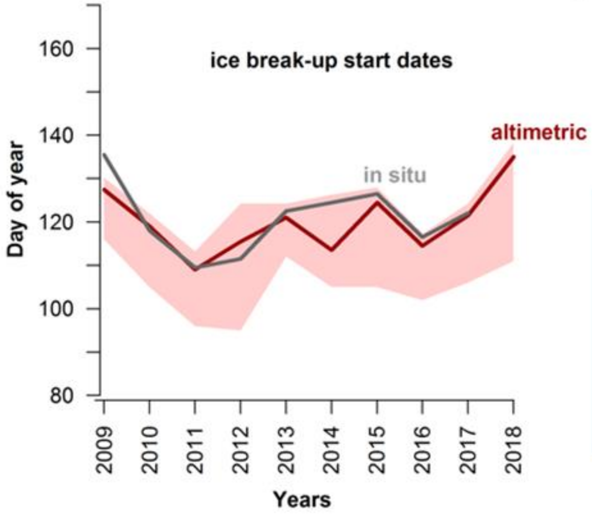
Monitoring the river ice regime: potential for ice roads operation.

(E. Zaharova, WPI RAS)

1. Retrieving the river ice parameters from satellite altimetry observations to assess climatic changes





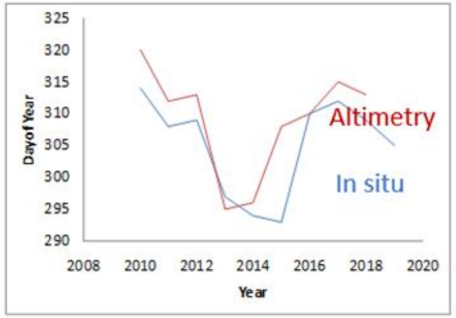


The approach seems to have a good potential in the future and can be adapted to ongoing and upcoming polar-orbiting satellites.

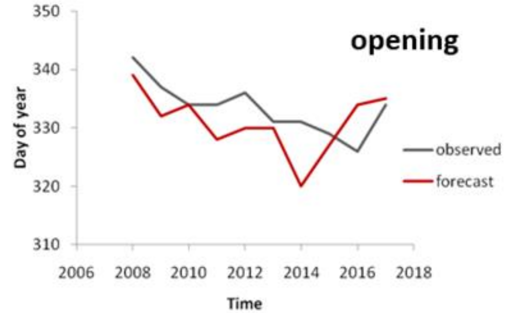
Pictures: ice regime parameters of the Ob river (Russia)

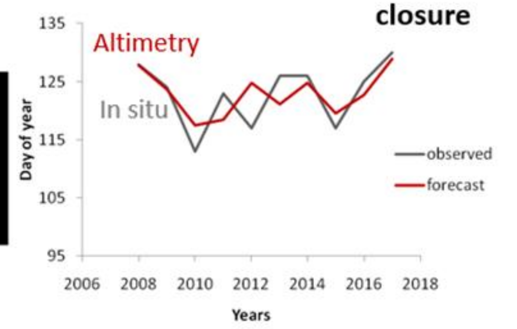
2. Developing the methods of forecast of ice road operation based on satellite data

Ferry closure dates



Ice road dates





Preliminary method of Salekhard City ice road operation forecast uses altimetry-derived ice thickness and ice break-up dates in upstream area

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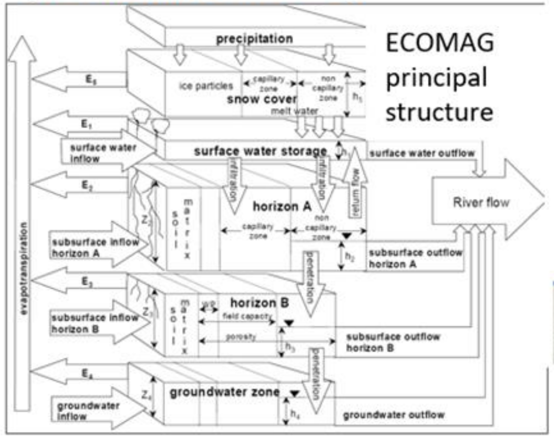
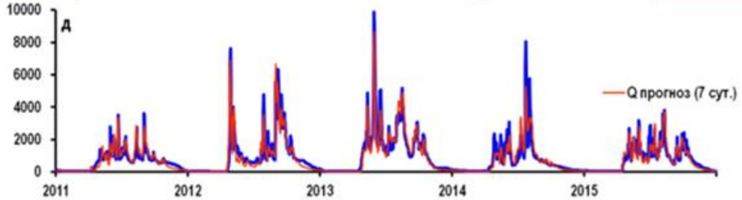
Flood risk management: linking satellite-derived data and hydrological models

Physically based semi-distributed hydrological model ECOMAG

(Yu.Motovilov, WPI RAS)

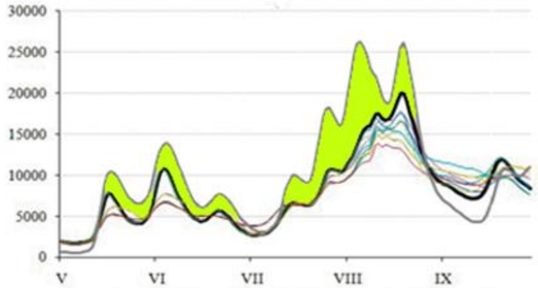


ECOMAG principal structure

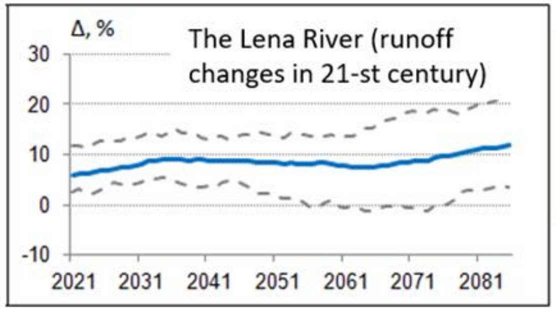


River runoff analysis and operational forecasts

Scenarios of hydrographs



Dam construction impacts on the runoff redistribution assessment

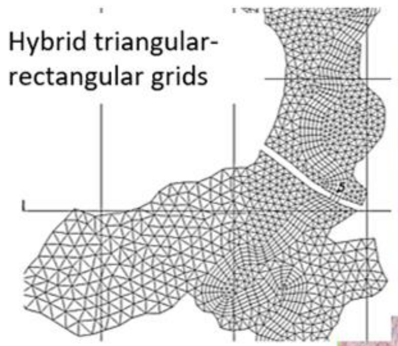


Long-term river runoff projections related to climate change

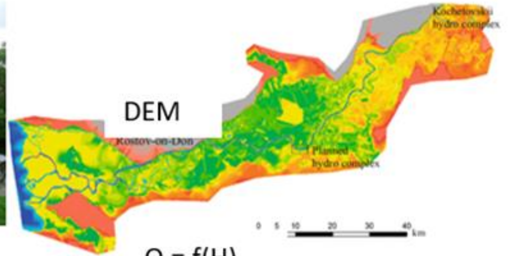
Numerical 2D hydrodynamic model STREAM 2D

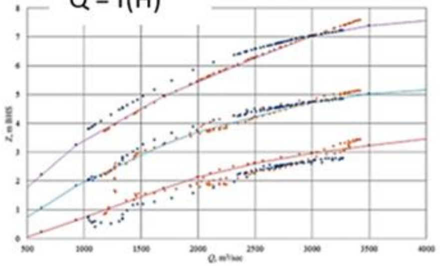
(V.Belikov, WPI RAS)

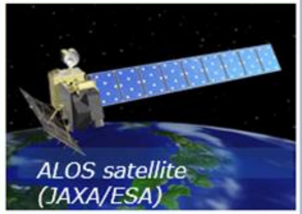
Hybrid triangular-rectangular grids

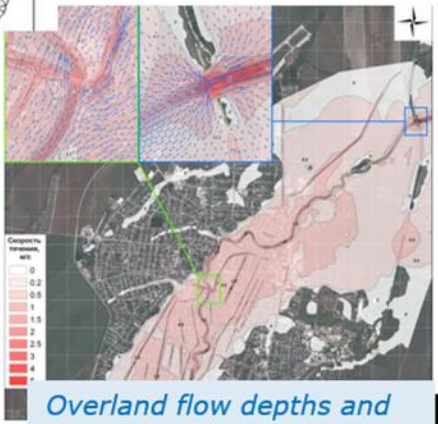


Dams, bridges etc. parameters assimilation

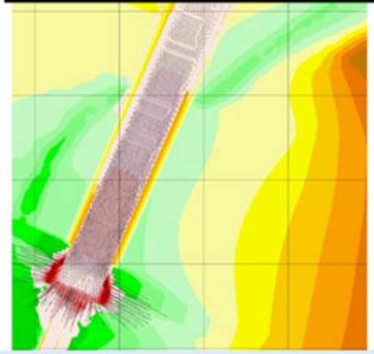




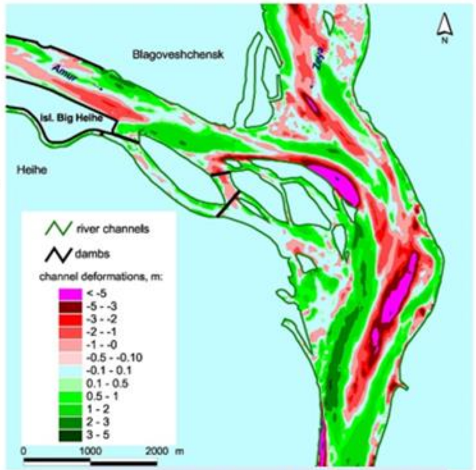




Overland flow depths and velocities



Dam break impact assessment and modelling



River bed and channel deformations

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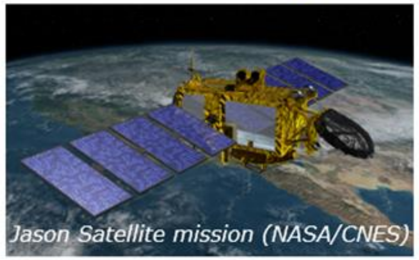
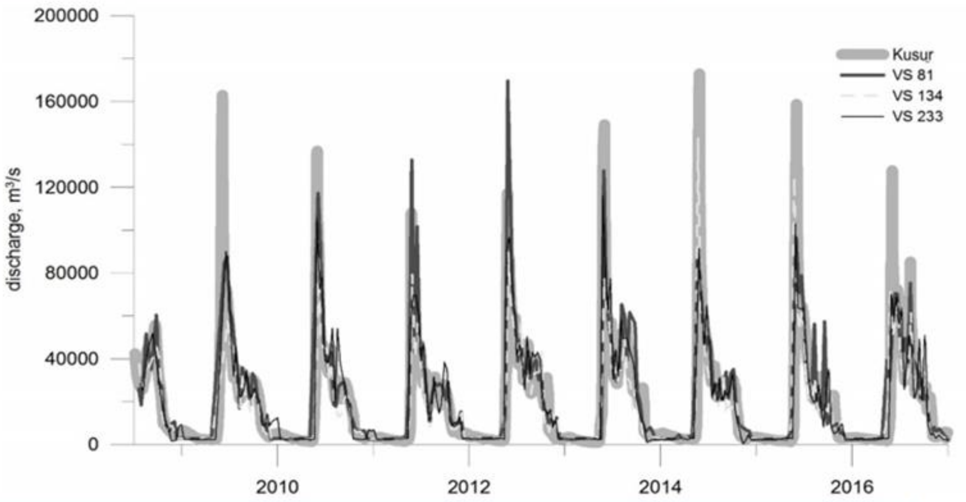
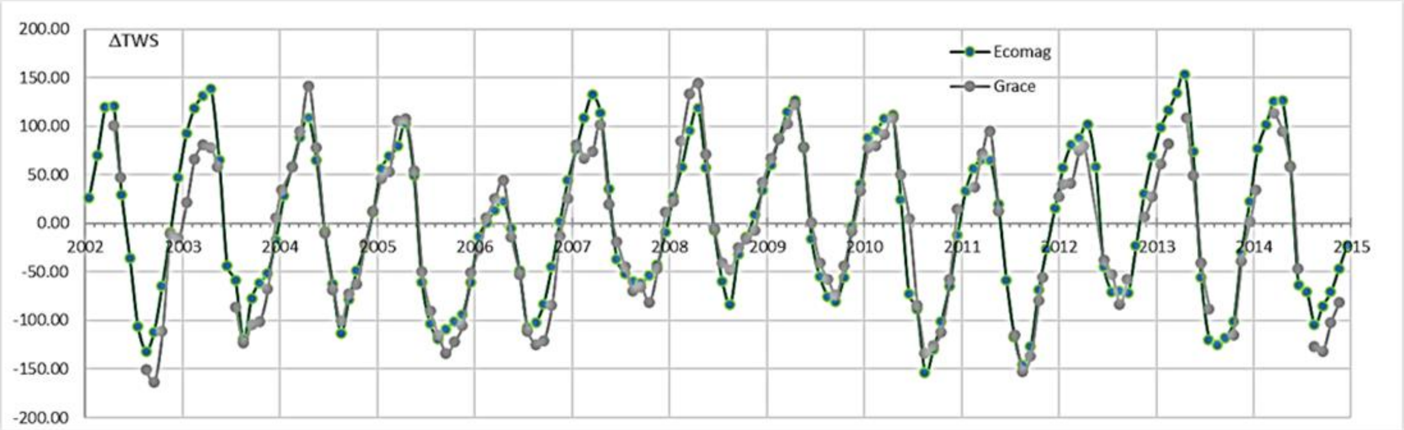
Flood risk management: linking satellite-derived data and hydrological models

Remote sensing data assists in hydrological modelling and river flow forecasting


Jason Satellite mission (NASA/CNES)

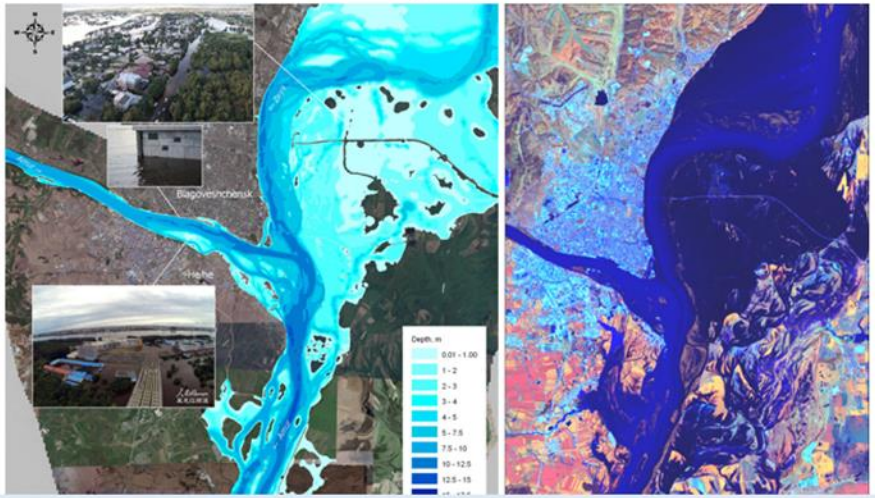


Observed (thick grey) and calculated daily water discharges at the mouth of the Lena river (Eastern Siberia, Russia). The data for calculation river runoff was derived from altimetry measurements of water stages along the river taken by Jason-2 and Jason-3 satellites (NASA/CNES).

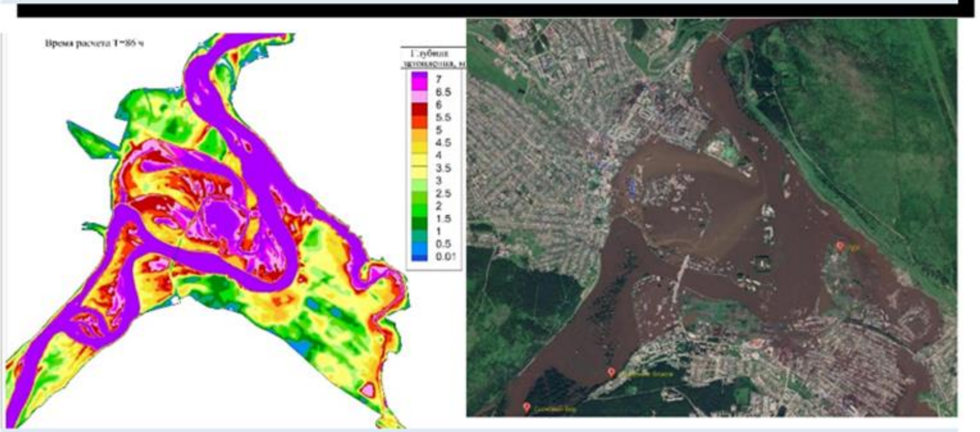


*Modelled (**ECOMAG** - green) and observed (GRACE - grey) anomalies of the total water storage (mm) within the drainage basin of the Northern Dvina river (Russia).*

Satellite imagery as a tool assisting in verification of hydrodynamic models



*Modelled (**Stream 2D** - left) and observed (Landsat - right) spatial distribution of water over the floodplain at the confluence of the Zeya and the Amur river (the Far East of Russia) during the historical flood in 2013.*



*Modelled (**Stream 2D** - left) and observed (right) spatial distribution of water over the floodplain of the Iya river (Irkutsk region of Russia) during the historical flood in 2019.*

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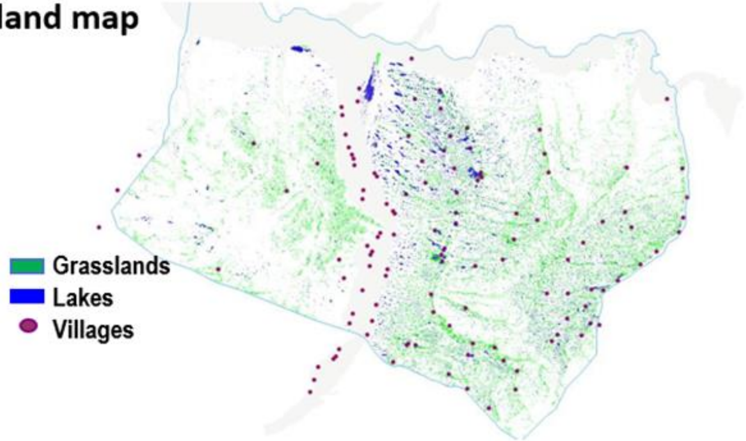
Hydro-climate variability and changes and societal challenges

Ecosystem service assessment based on satellite and ground observations

- Central Yakutia : unique agriculture practices developed in thermokarst environment
- Ecosystem productivity depends on **water availability**
- Sharp cyclic **changes of hydro-climate conditions**
- Vulnerable agriculture requiring a rapid adaptation

1. Landsat-derived lake and grassland map



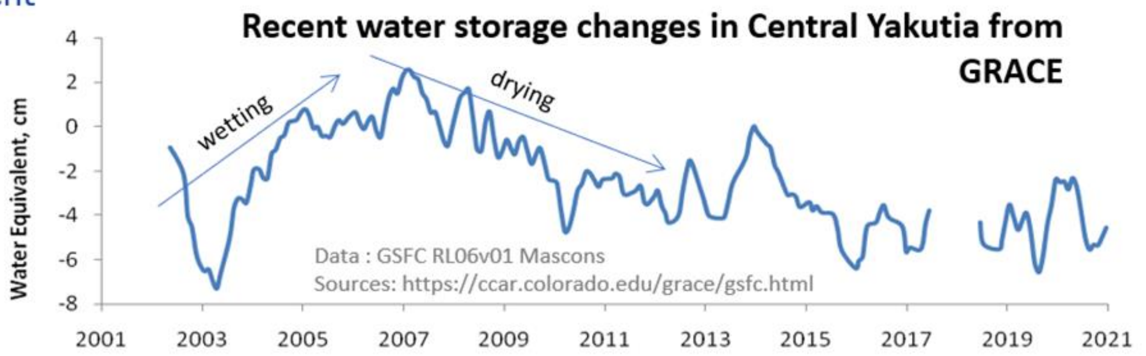
2. Regional assessment of hay needs and ecosystem production capacity from satellite and ground data:

Hay needs for livestock in 2015-2017 :	*320*10³ t/y*
Alas ecosystem hay production capacity in wet years:	*495*10³ t/y*
Alas ecosystem hay production capacity in dry years:	*415*10³ t/y*

Good potential of thermokarst ecosystems under smart management:

*- **water regime monitoring** (effect on soil waterlogging, salinisation, thermokarst development)*

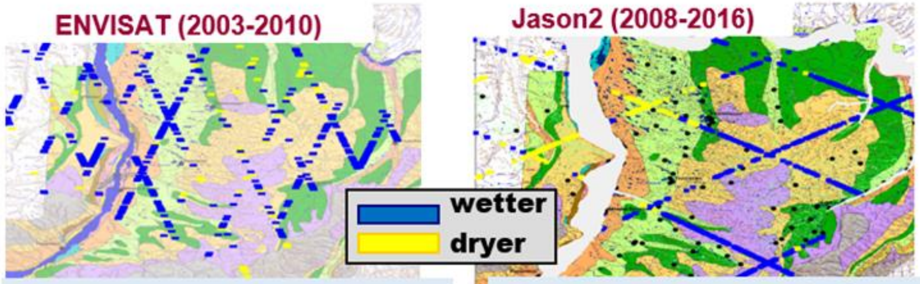
- road network development and maintenance (accessibility of grasslands, avoid overexploitation of nearest grasslands)



3. Water regime monitoring:

(E. Zaharova, WPI RAS)

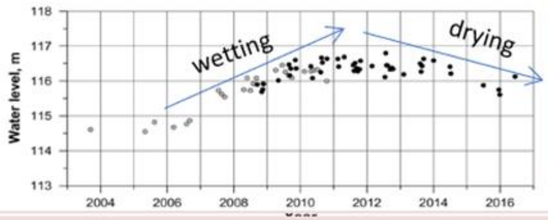
3.1 Altimetry-derived wetting/drying trends



Wetting: expansion of lakes almost everywhere

Drying: contrast trends depending on local permafrost conditions

3.2 Altimetry-derived lake water level



Mean lake water level rise in 2003-2011 was 1.3 m,

Mean lake water level drop in 2011-2016 was 0.7 m

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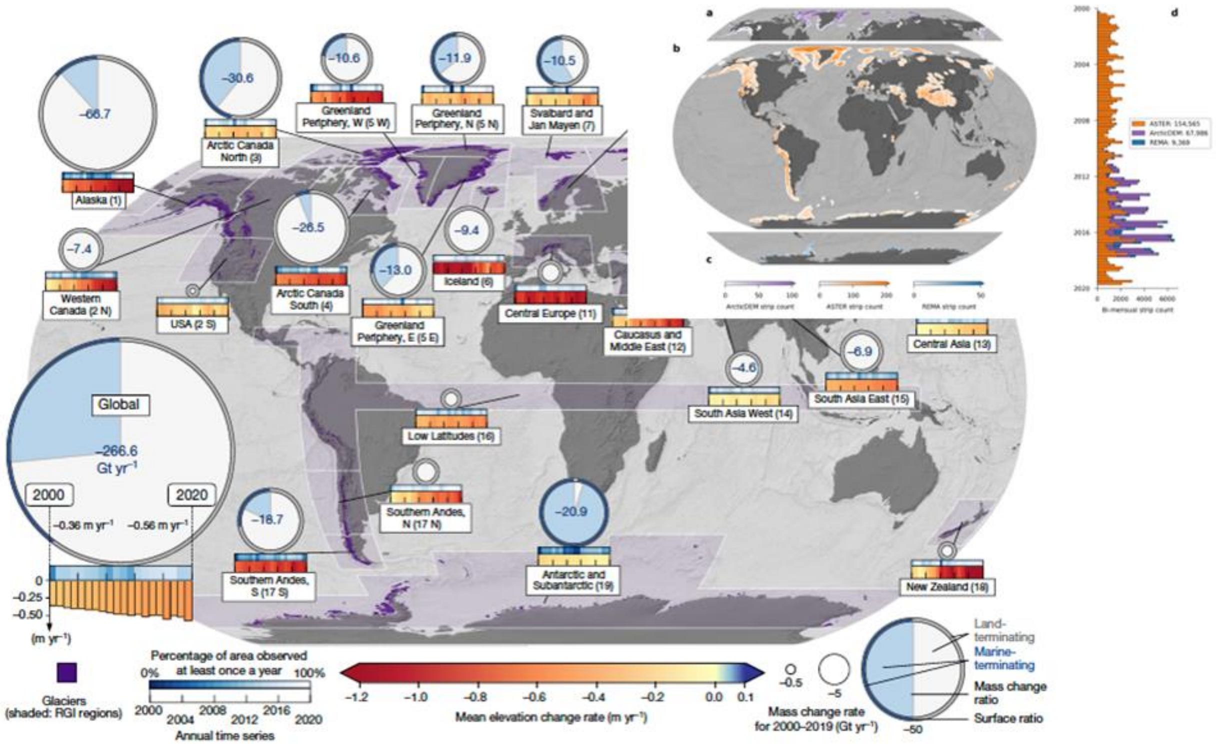
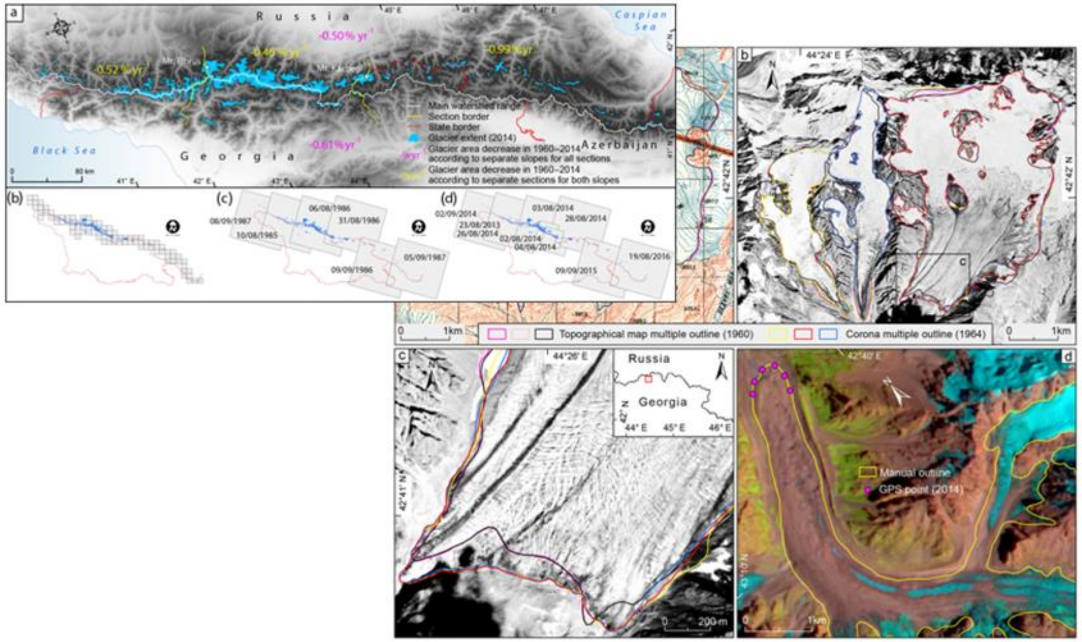
Unprecedented rates of global glacier mass loss in the early twenty first century

1 Monitoring global glacier mass loss



Hugonnet et al (2021) used NASA's 20-year-long archive of stereo images from ASTER to estimate Earth's surface elevation over all glaciers and their vicinity between 1 January 2000 and 31 December 2019. Nearly half a million DEMs, covering more than 20 times Earth's land area were generated and bias-correct by means of Modern photogrammetry techniques and specifically developed statistical methods

2 Main sources of error in modelling of glacier mass loss and glacial runoff dynamics that are difficult to automatically mitigate include inaccurate and/or outdated glacier outlines, cloud cover and topographic shading



Glacier inventory at three time periods (1960, 1986, 2014) covering the entire Greater Caucasus was developed by Tielidze et al (2018). Large-scale topographic maps and satellite imagery (Corona, Landsat 5, Landsat 8 and ASTER) were used to conduct a remote-sensing survey of glacier change, and the 30 m resolution Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model (ASTER GDEM; 17 November 2011) was used to determine the aspect, slope and height distribution of glaciers.

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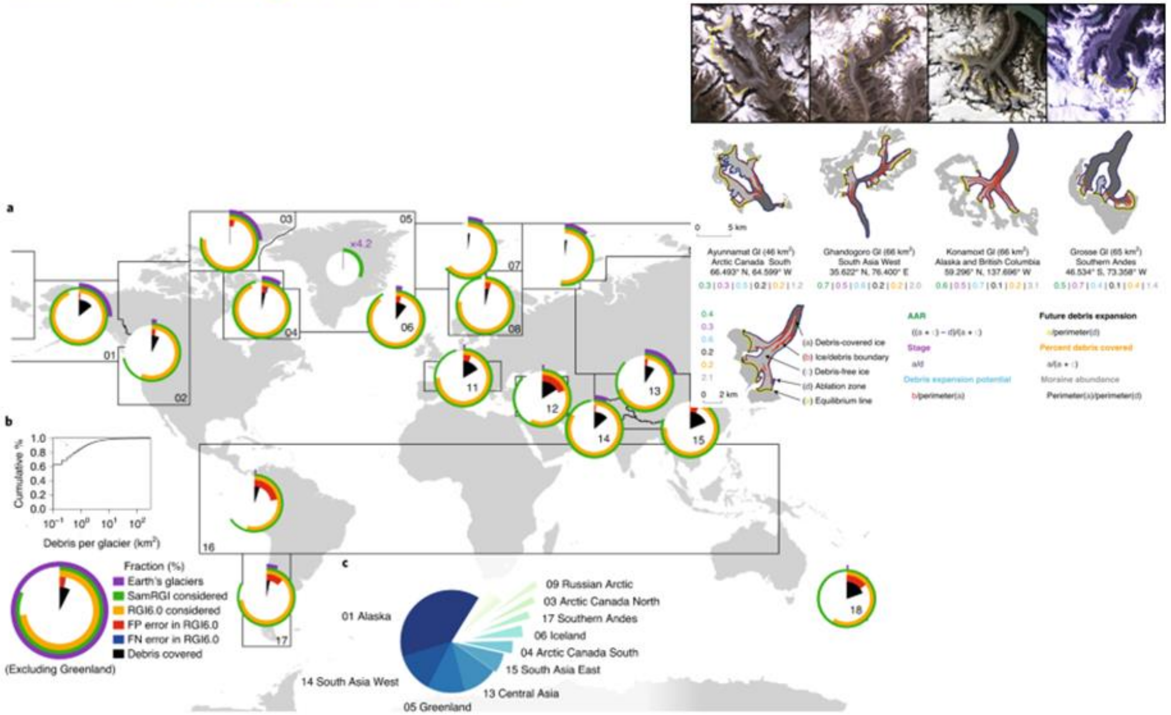
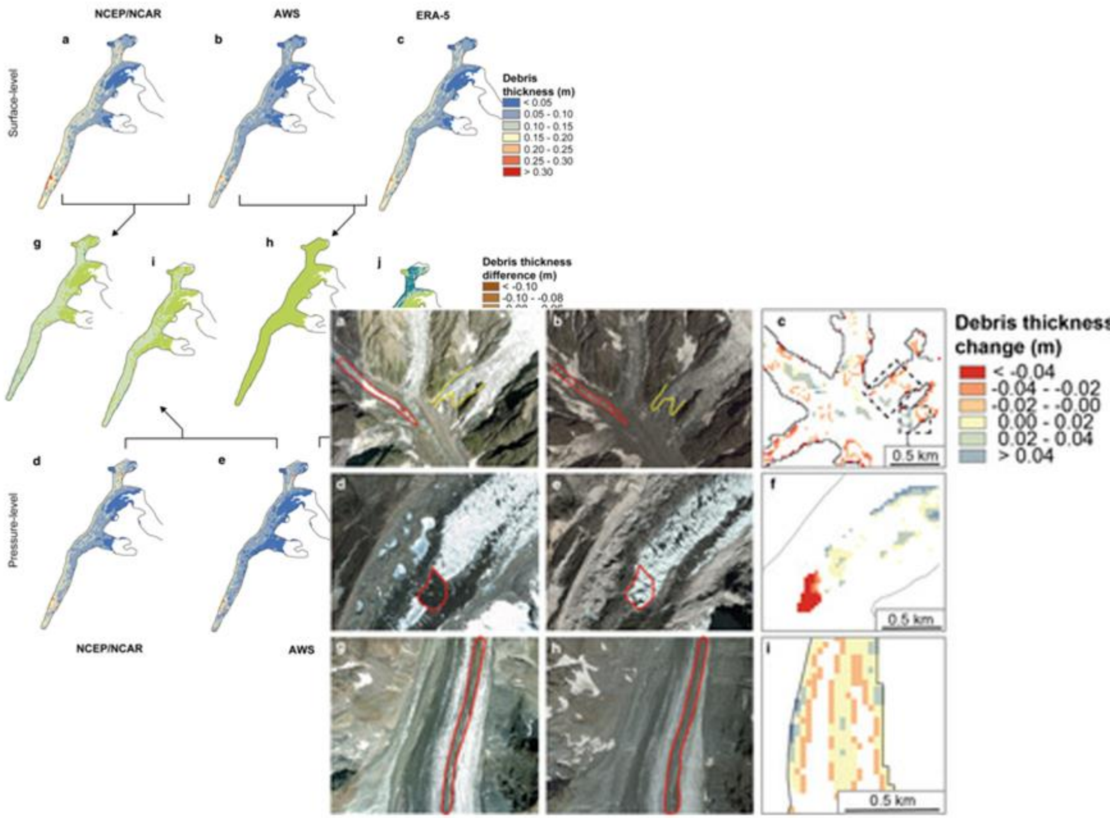
Towards global debris cover mapping: debris cover is changing the way glaciers melt as it further spreads

Between the evidence that debris cover is expanding and its omission in global glacier models, three remaining fundamental unknowns need to be resolved to close this knowledge gap: the spatial distribution, thickness and three-dimensional (3D) evolution of supraglacial debris





Debris cover is present on 44% of Earth's glaciers and prominent (>1.0 km2) on 15%. Globally 7.3% of mountain glacier area is debris covered. Herreid and Pellicciotti (2020) use a big data approach and apply a semi-automated method, relying on Landsat imagery and a detailed correction to the Randolph Glacier Inventory to construct a dataset that enables improved estimates of melt over 10.6% of the global glacier domain in global-scale models

Surface energy-balance models are commonly used in conjunction with satellite thermal imagery to estimate supraglacial debris thickness. In (Steward et al., 2021) ERA-5 data were then used to estimate spatiotemporal changes in debris thickness over a ~20-year period for Miage Glacier, Khumbu Glacier and Haut Glacier d'Arolla, Switzerland.

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Thank you for your attention

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