

INTAROS Open Webinar, Arctic Science Summit Week, 2022-03-28

# **Pan-Arctic River Discharge Monitoring and Modelling**

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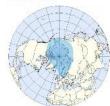


This work has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No [727890]



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#### Arctic-HYCOS



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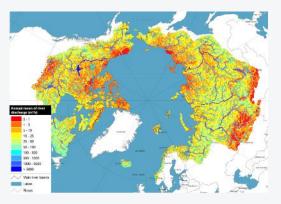
### Arctic-HYCOS

- Hydrological monitoring in the Pan-arctic drainage basin of the Arctic Ocean (PADB)
- National hydrological services in Arctic countries
- Sweden/SMHI: development and operation of Arctic-HYPE panarctic hydrological model



#### WHOS – WMO Hydrological Observing System

- Arctic-HYCOS observations available in a common system (not available at the start of INTAROS)
- Assimilated in Arctic-HYPE pan-arctic hydrological model



#### Arctic-HYPE

- PADB setup of HYPE model
- Developed in collaboration with research groups in Canada and Russia (Arctic-HYPE modelling community)
- Open data:
  - historical analysis 1979-, 10 day forecasts
  - provided by OPENDAP server (thanks to INTAROS!)
- River ice, permafrost, non-contributing areas, sparse observation network (>40% un-gauged areas)





🏘 / Organizations / Swedish Meteorological and... / Arctic-HYCOS hydrological data / Arctic-HYCOS-hydrological-d...

#### Arctic-HYCOS-hydrological-data-station-network.png

URL: https://portal-intaros.nersc.no/dataset/54ff2c79-66ad-410f-bd28-3754b6497b74/resource/98265690-14e6-4355-a214-eee2a27a4e1a/download/bild2.png

The Arctic-HYCOS observing system provides daily and monthly gauged river discharge data from a selection of stations operated by the national hydrological services (NHS) in the Arctic Council member states (Canada, Denmark, Finland, Iceland, Norway, Russian Federation, Sweden and United States of America). The observation system is established by the Arctic-HYCOS project (https://hydrohub.wmo.int/en/projects/Arctic-HYCOS). The set of stations have been selected to provide a basis for monitoring fresh water flow to the Arctic Ocean and for monitoring changes in the hydrological regime. The current list includes 423 stations of which 72 are listed as flow-to-ocean stations, representing the most reliable downstream station in the river basins. The Global Runoff Data Centre (GRDC, http://www.bafg.de/GRDC) serves as a focal point redistributing historical data and station metadata, whereas provisional and (when available) near-real-time data should be provided directly by the NHS.

#### H2020 INTAROS Integrated Arctic Observation Systems

Ownload



# Legend Flow-to-ocean stations Hydrological regime stations Upstream area of stations Arctic ocean drainage basin AMAP region 1

#### Assessment of Arctic-HYCOS observation system

- + Temporal (up to +100yrs) and spatial (~60%) coverage
- + Sustainable funding and organization

-/+ Partly poor (but improving) data access and latency time

#### Arctic hydrological modelling cases (WP6)

- Pan-arctic hydrological modelling (Arctic-HYCOS)
- Regional hydrological modelling in Yakutia (HYPE-ERAS)



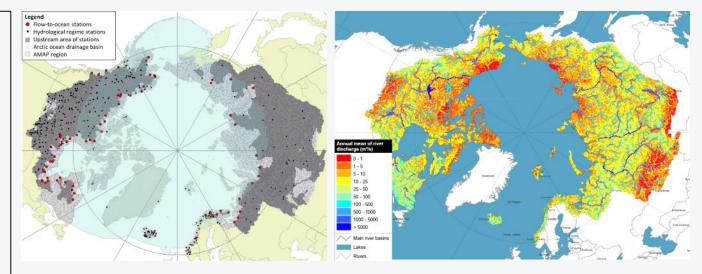
## Arctic-HYPE: Hydrological Modelling and Prediction for Arctic-HYCOS

#### <u>Aim:</u>

Contribute to monitoring of river flow to Arctic Ocean and changes in arctic hydrological regimes (ungaged flow ~40% Pan-arctic drainage basin)

#### Arctic-HYPE

- 25.10<sup>6</sup> km<sup>2</sup> pan-arctic drainage basin
- ~33000 sub-basins (mean ~800 km<sup>2</sup>)
- Forcing 1979-present (HydroGFD; Berg et al, 2017)
- Analyses and forecast (1-10 days) assimilating Arctic-HYCOS data



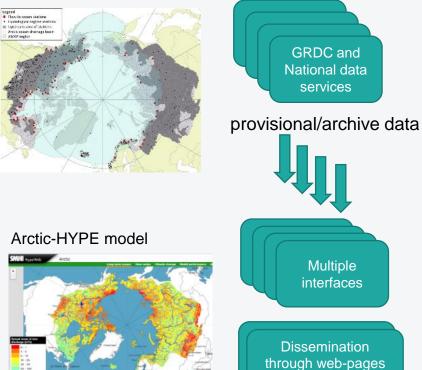
https://hypeweb.smhi.se/explore-water/geographical-domains/#arctichype



## iAOS / WHOS integrated observation systems

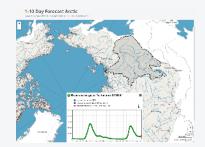
and ftp sites

#### Arctic-HYCOS observations



#### Status before INTAROS / WMO WHOS

- Multiple interfaces for each provider and variable
- Uncertainty of data update/versions
- Variability in data and metadata format

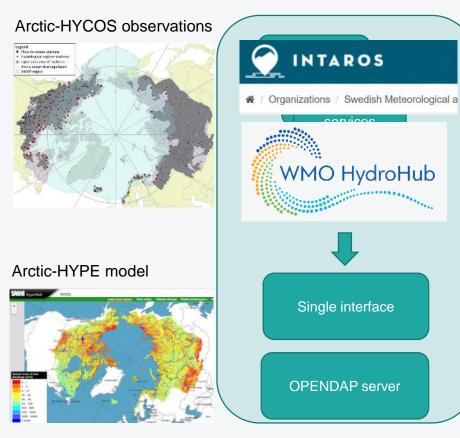


Model output without observations Interactive web-site Limited interoperability

https://hypeweb.smhi.se/explore-water/forecasts/short-medium-range-forecast-artic/



## iAOS / WHOS integrated observation systems



#### INTAROS IAOS / WMO WHOS

- Single interface to different data providers
- Linking to original data provider (latest data version)
- Conforming data and metadata format

#### Model dissemination by OPENDAP server User services combining model and observations



#### Hydrology, Permafrost and resilience in East Russian Arctic and Sub-Arctic (<u>HYPE-ERAS</u>)



Environmental change  $\iff$  Societal challenges



#### **HYPE-ERAS** research themes

- Water in Yakutian life
- Where water comes from
- New flood hazard knowledge
- Permafrost landscape change
- Roads on thinner ice
- Understanding climate change
- Hydrological modelling and
  - forecasting

Republic of Sakha (Yakutia), Russia



Study area and project partners from Sweden, Russia, and Japan

#### https://hype-eras.org

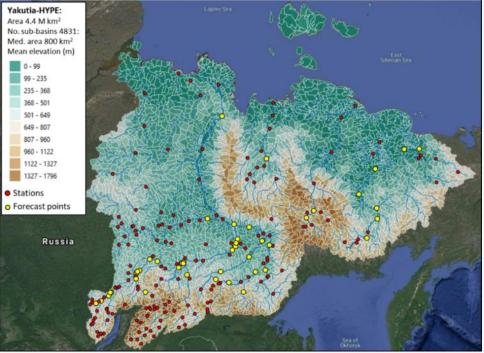
## HYPE - Hydrological Predictions for the Environment model (Lindström et al, 2010)



## Yakutia-HYPE: a local adaption of Pan-arctic and World-wide HYPE models

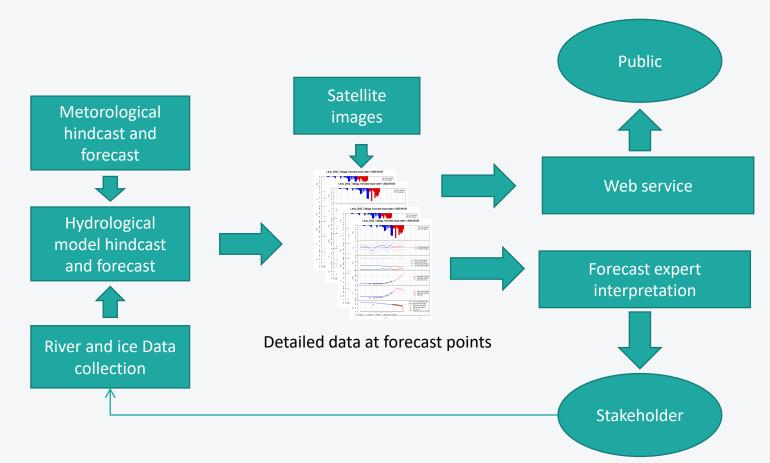
(Arheimer et al, 2020; http://hypeweb.smhi.se)

- Semi-distributed hydrological model
- Water balance in snow, soil, glaciers, lakes, river network
- Lake and River ice growth/melt and breakup
- Water level prediction by transforming simulated discharge using empirical rating-curves
- Simplified frozen soil impact on infiltration and runoff (not permafrost model)
- Yakutia-HYPE setup:
  - ~4800 sub-basins with 60 sub-classes for different combinations of soil and landcover types
  - Meteo-input: Hydro-GFD (bias-corrected ERA5+ECMWF forecast, Berg et al, 2018/2020)
- Co-developed by SMHI and MPI
- ~120 discharge and water level gauging station for calibration, evaluation and assimilation



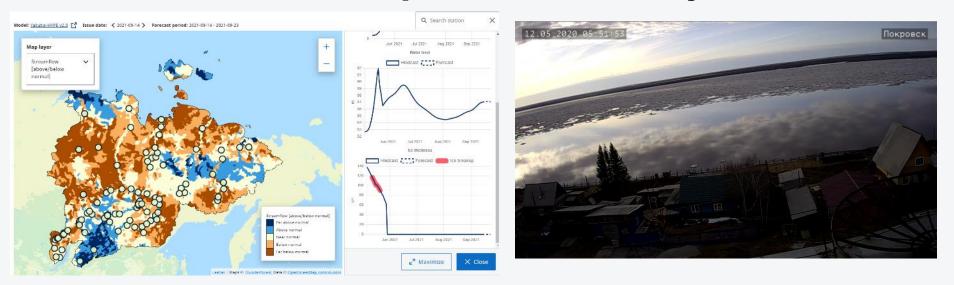
## Forecast production chain and dissemination







#### **HYPE-ERAS - River ice breakup and flood forecast system**



https://www.smhi.se/forskning/forskningsnyheter/islossningsprognos-for-floden-lena-ovantat-saker-pa-forsta-forsoket-1.160406



HYPE-ERAS is funded by FORMAS, RFBR and JST through the Belmont Forum Collaborative Research Action: Resilience in the Rapidly Changing Arctic

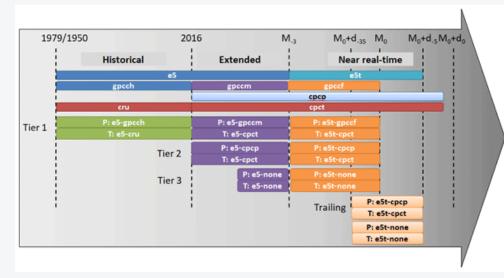
#### https://hype-eras.org/forecasts

HydroGFD3.0 (Hydrological Global Forcing Data): a 25 km global precipitation and temperature data set updated in near-real

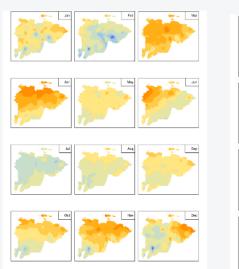
time Berg *et al*, Earth Syst. Sci. Data, 13, 1531–1545, 2021 https://doi.org/10.5194/essd-13-1531-2021

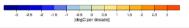
#### ERA5 re-analysis corrected by different P and T obs

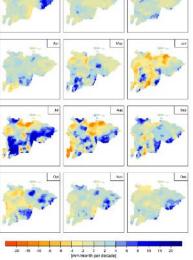
Time period: 1950 –> near real time Temporal/spatial resolution: daily/25km

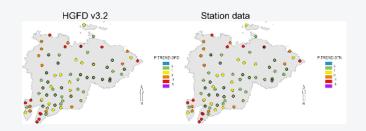


Trends in 2m air temperature: 1991-2020 Trends in precipitation: 1991-2020





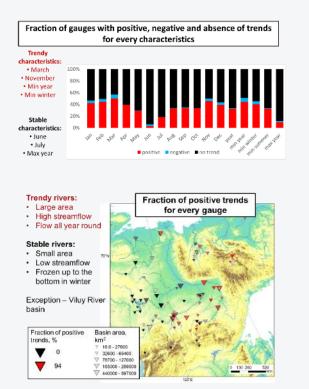




Trends in annual precipitation (mm/yr), 1980-2019 Stations with significant trends marked by thick line

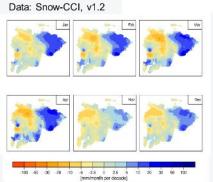
#### **Relation between snow and seasonal characteristics** of hydrological change (spatially and temporally)



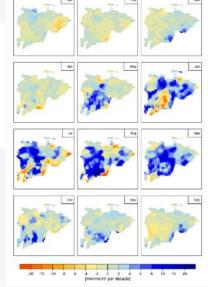


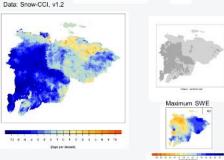
From Lebedeva & Gustafsson, 2021 https://doi.org/10.3390/w13192747

#### Trends in maximum SWE: 1989-2018 Trends in precipitation: 1981-2010



# Trends in SWE - number of days > 5mm: 1989-2018

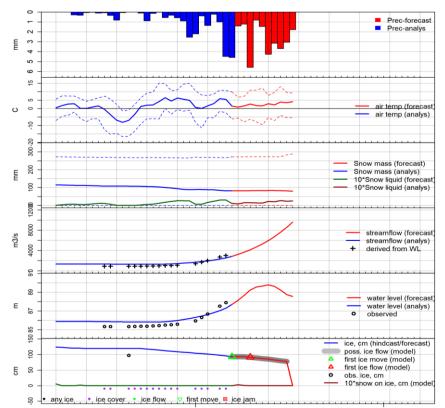




#### Snow CCI Phase 1 manuscript in preparation

## River ice breakup in Yakutsk 2020-05-11/12





Forecast for Lena river at Tabaga issued 2020-05-08 (Friday) predicting first ice flow during period 8th – 11th of May (red triangle)

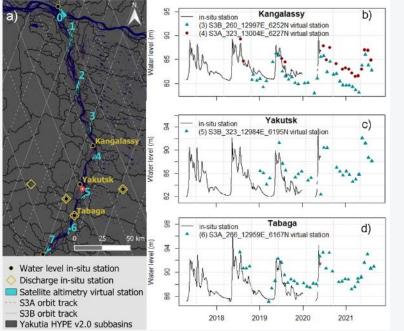
First ice flow was observed 2020-05-10

#### Please note:

The "bump" in the water level is a result of a transition in the **rating curve parameters** from ice to ice free conditions

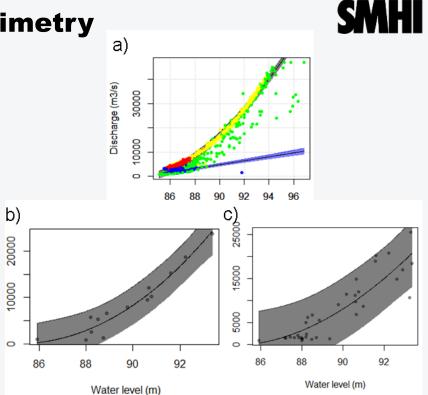
(ice jamming is not predicted by the model)

https://www.smhi.se/en/research/research-news/forecasts-of-river-ice-break-up-for-the-lena-riverunexpectedly-accurate-on-the-first-attempt-1.160535



In situ and virtual stations for water level and discharge monitoring in the Lena River in central Yakutia

# **River monitoring by Satellite altimetry**



Rating curves for Lena river at Tabaga station using (a) insitu discharge and in situ water level (b) in situ discharge and satellite altimetry water level, and (c) simulated discharge and satellite altimetry water level



# Summary

- Arctic-HYCOS observation system:
  - river discharge data from major Arctic rivers
  - Represents ~60% of the pan-arctic drainage basin of the Arctic Ocean.
  - Well established and sustainable (national hydrological services NHS)
  - Partly FAIR through WMO, GRDC and NHS data services
  - Areas of improvement interoperability and reusability
- Arctic-HYPE modelling case studies:
  - Pan-arctic: <u>https://hypeweb.smhi.se/explore-water/forecasts/short-medium-range-forecast-artic/</u>
  - Yakutia (paused): <u>https://hype-eras.org/forecasts/</u>



## **Arctic-HYCOS data sources**

National Hydrological Institutes / INTAROS

https://catalog-intaros.nersc.no/dataset/arctic-hycos-hydrological-data

GRDC

https://www.bafg.de/GRDC/EN/04\_spcldtbss/41\_ARDB/ardb\_node.html ;jsessionid=327E4AE8D7D5BFD76747335897DD4470.live11314

WMO

https://hydrohub.wmo.int/en/projects/Arctic-HYCOS



## **Thank you!**

#### Northern Research Basins Workshops & Symposium www.nrb23.se

August 26 2022 at <u>www.cryosphere2022.is</u> August 2023 in Sweden



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