Response of Arctic sea level and hydrography to hydrological regime change over boreal catchments (RASLyBoCa)

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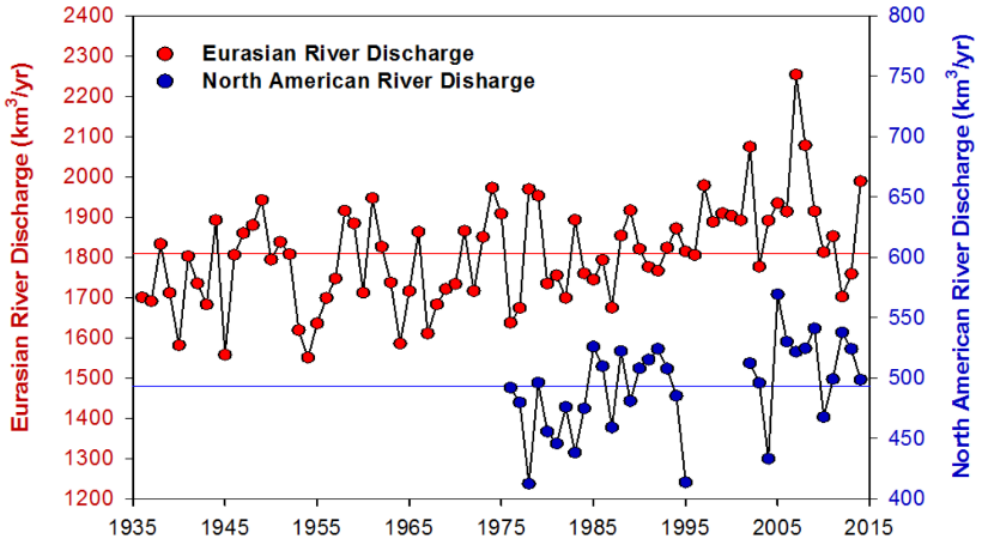
RASLyBoCa Project

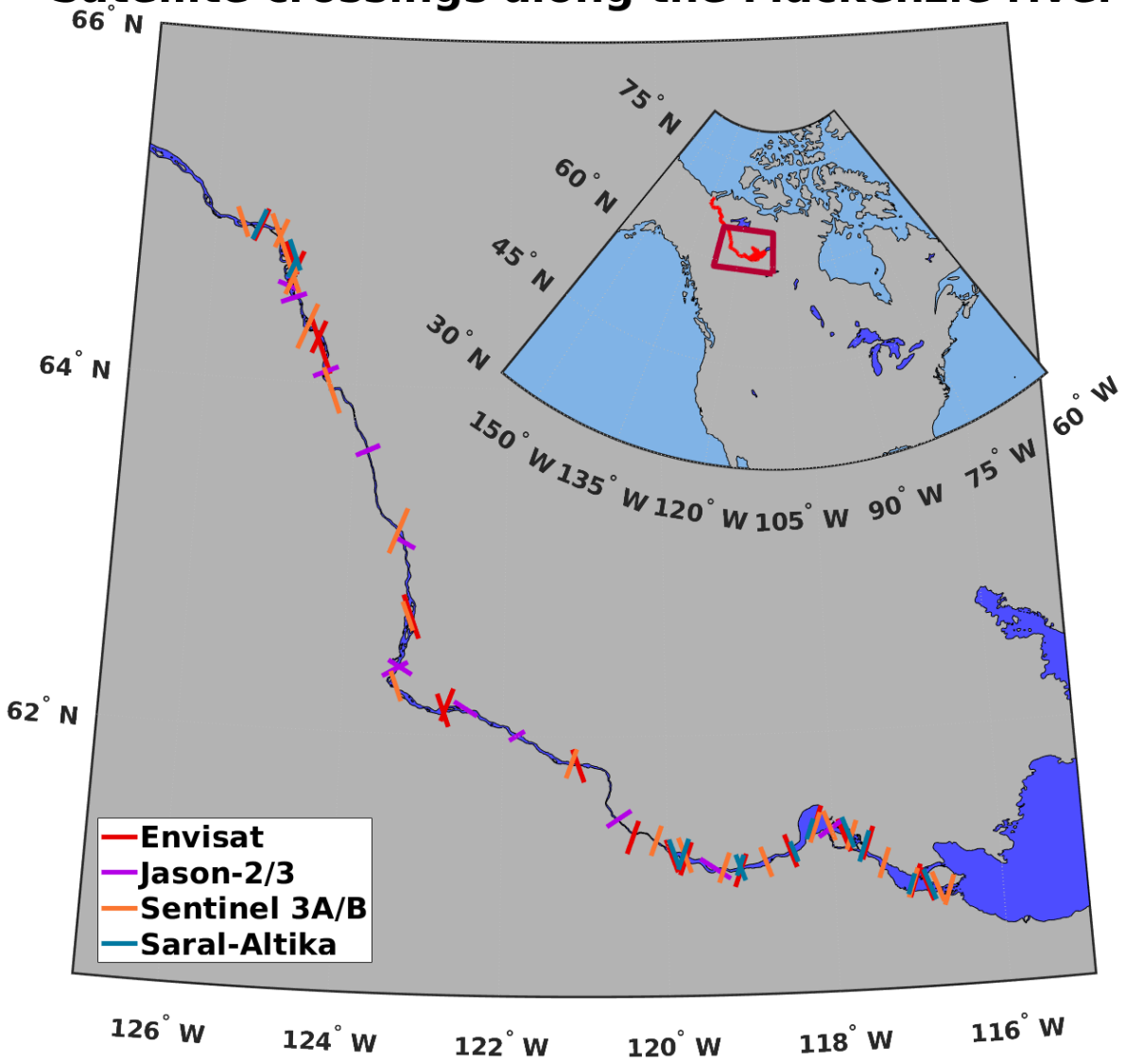
- Hydrological regime change over Boreal Catchments →response of Arctic Sea Level and hydrography
- Focus on continental discharge into the Arctic Ocean, as it may significantly influence the regional dynamics
- A wide range of observation techniques is used, such as
  - in-situ data
  - satellite altimetry data
  - satellite gravimetry data
  - numerical simulations with forward and "adjoint/dual" models



(Holmes et al., 2015)

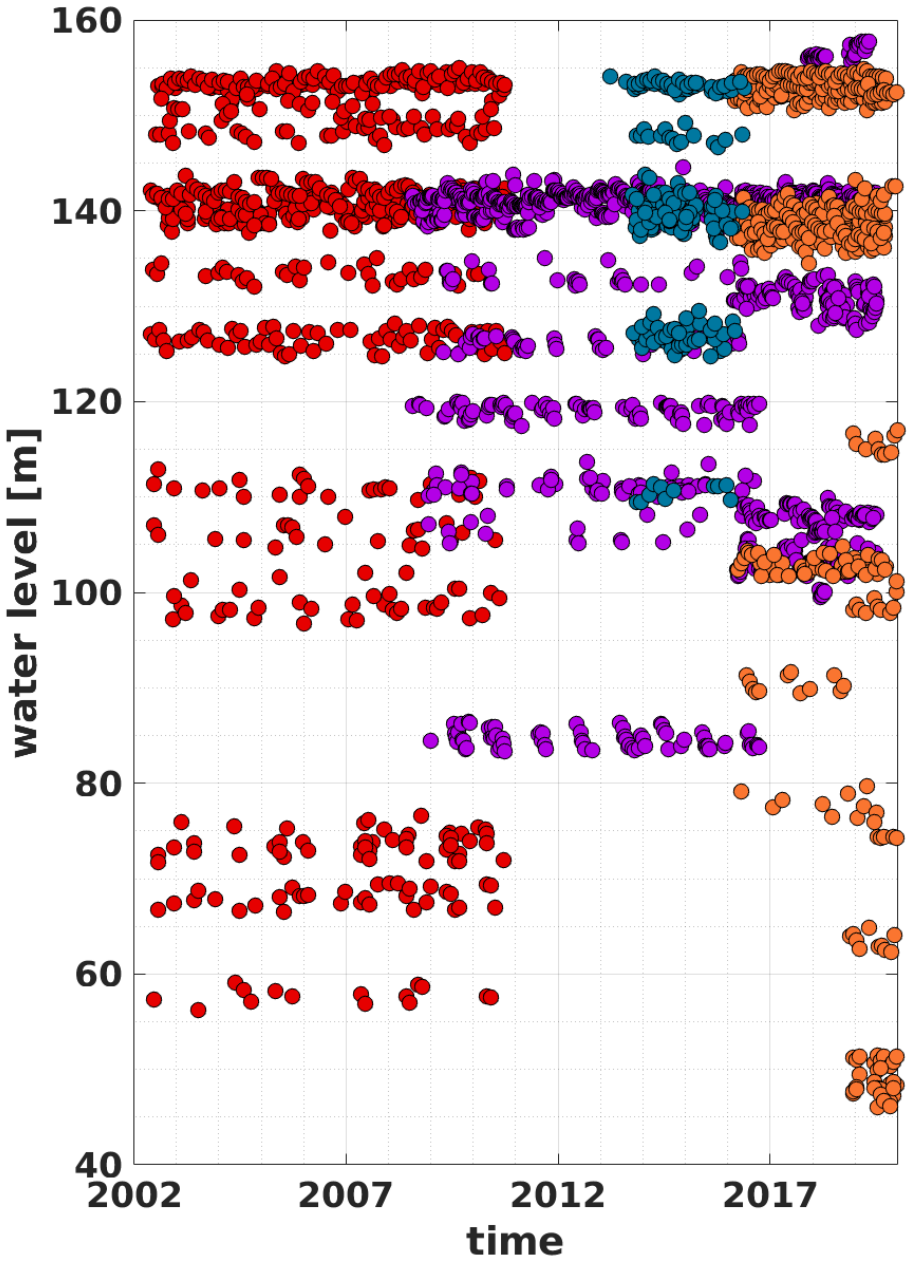
Problem statement

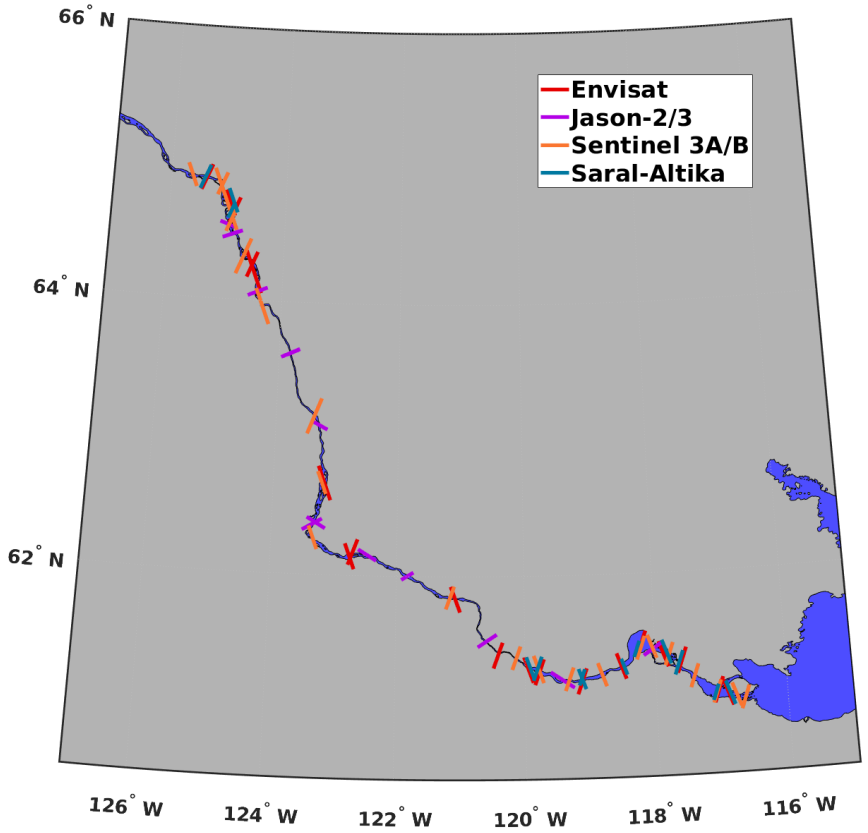
Satellite crossings along the Mackenzie river



Satellite	Repeat track [days]
Envisat	35
Jason-2/3	10
Saral/Altika	10
Sentinel 3A/B	27

Densification

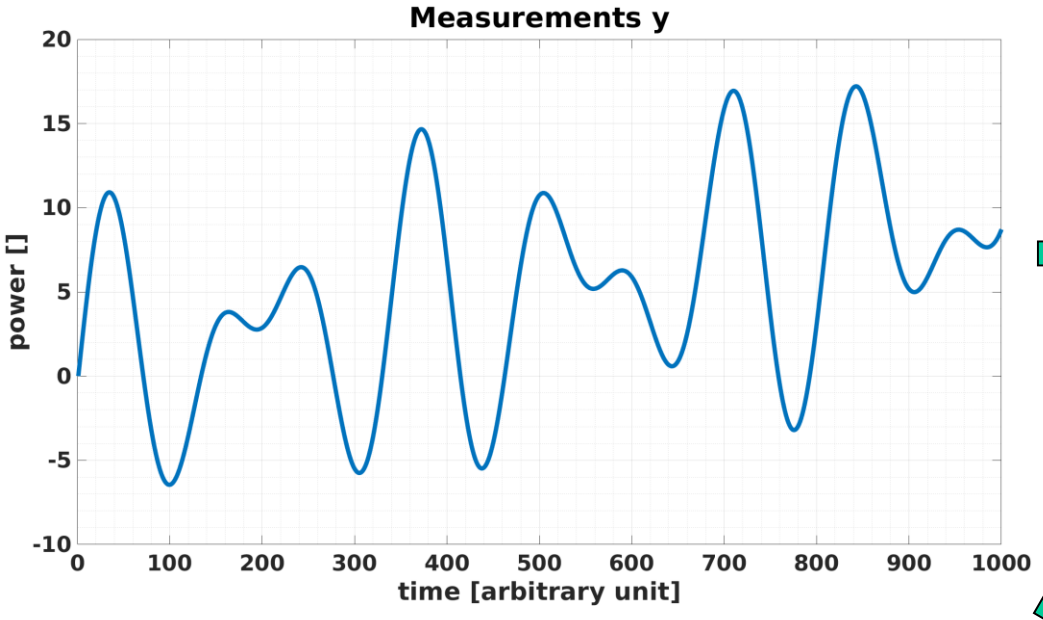


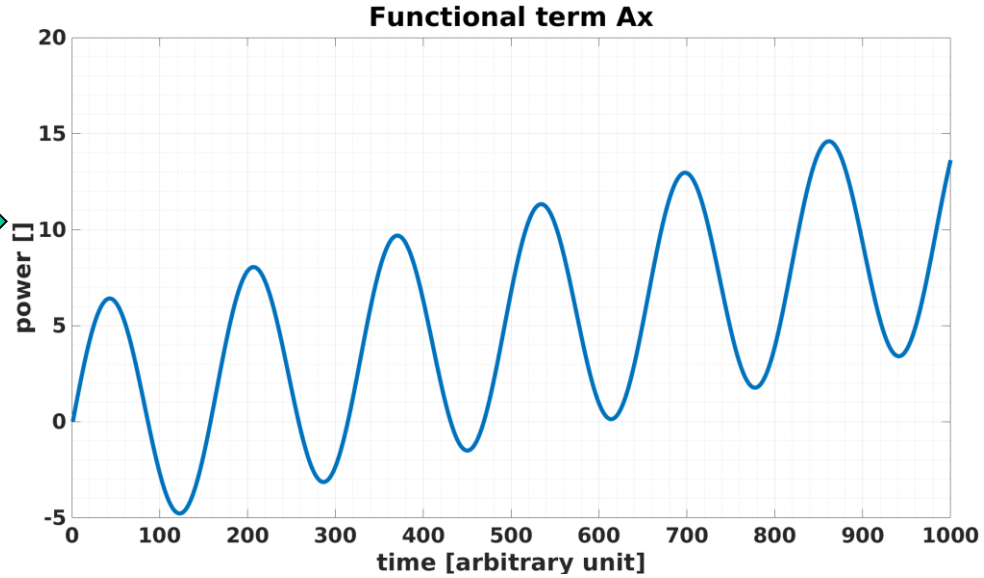


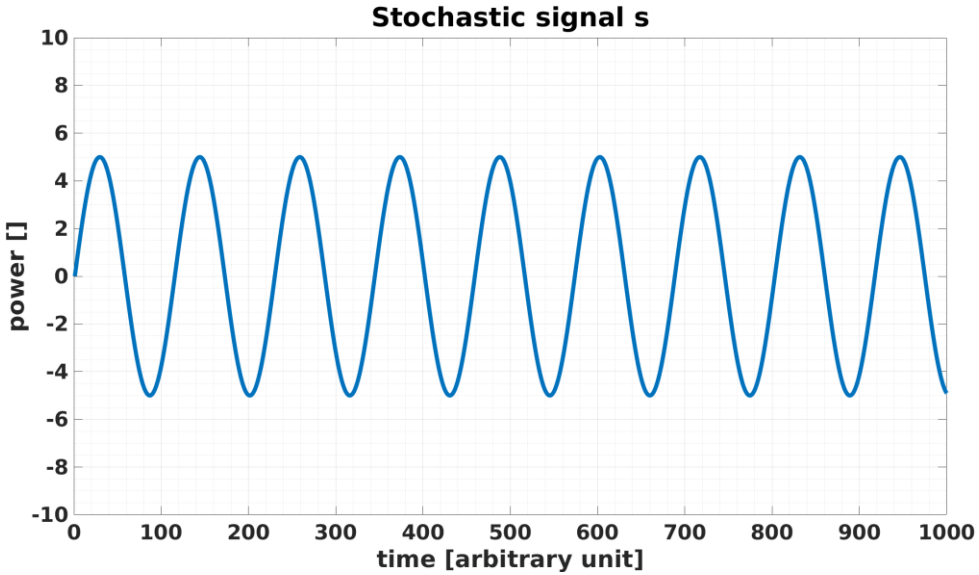
Densification

- Combining measurements in time and space
- Estimating water levels at
  - Any place
  - Any time

Least squares collocation (LSC)







Observation equation:

$$\boldsymbol{y = Ax + s + n}$$

$\boldsymbol{y}$ - measurement
$\boldsymbol{Ax}$ - functional term
$\boldsymbol{s}$ - stochastic signal
$\boldsymbol{n}$ - noise

LSC- Method

$$y = Ax + s + n$$
$$y - Ax = s + n$$
$$Q_{ee} = Q_{ss} + Q_{nn}$$

Linear equation model

$$\hat{x} = (A^T Q_{ee}^{-1} A)^{-1} A^T Q_{ee}^{-1} y$$
$$\hat{s} = Q_{ss} Q_{ee}^{-1} (y - A\hat{x})$$
$$\hat{n} = Q_{nn} Q_{ee}^{-1} (y - A\hat{x})$$

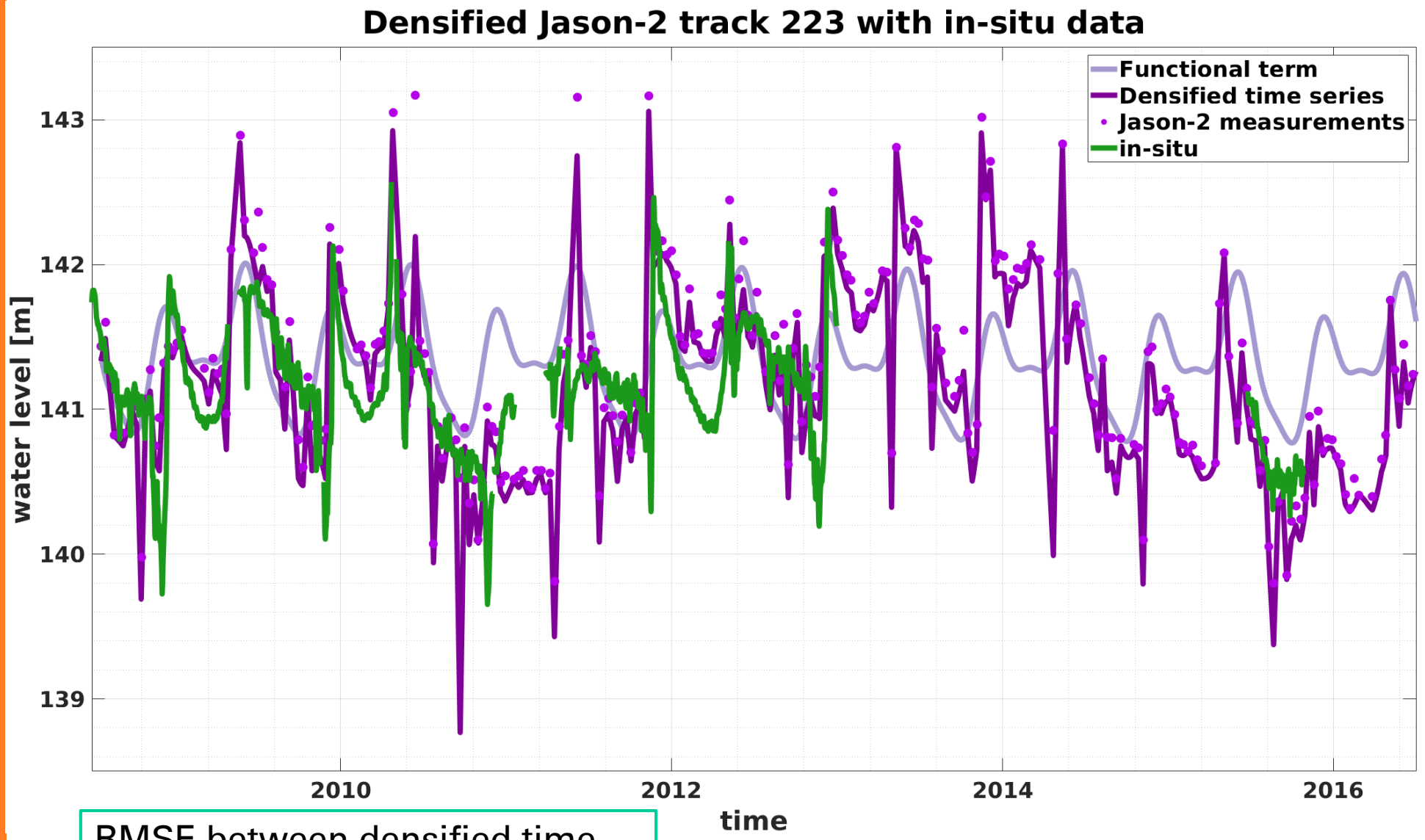
Estimation step

$$\hat{s}_{\mathrm{d}} = Q_{\hat{s}_{\mathrm{d}}\hat{s}} Q_{\hat{s}\hat{s}}^{-1} \hat{s}$$
$$\hat{y}_{\mathrm{d}} = A_{\mathrm{d}} \hat{x} + \hat{s}_{\mathrm{d}}$$

Densification in time

y – measurement
s – signal
Ax – functional term
n – noise
e – residuals

LSC – Results and Outlook

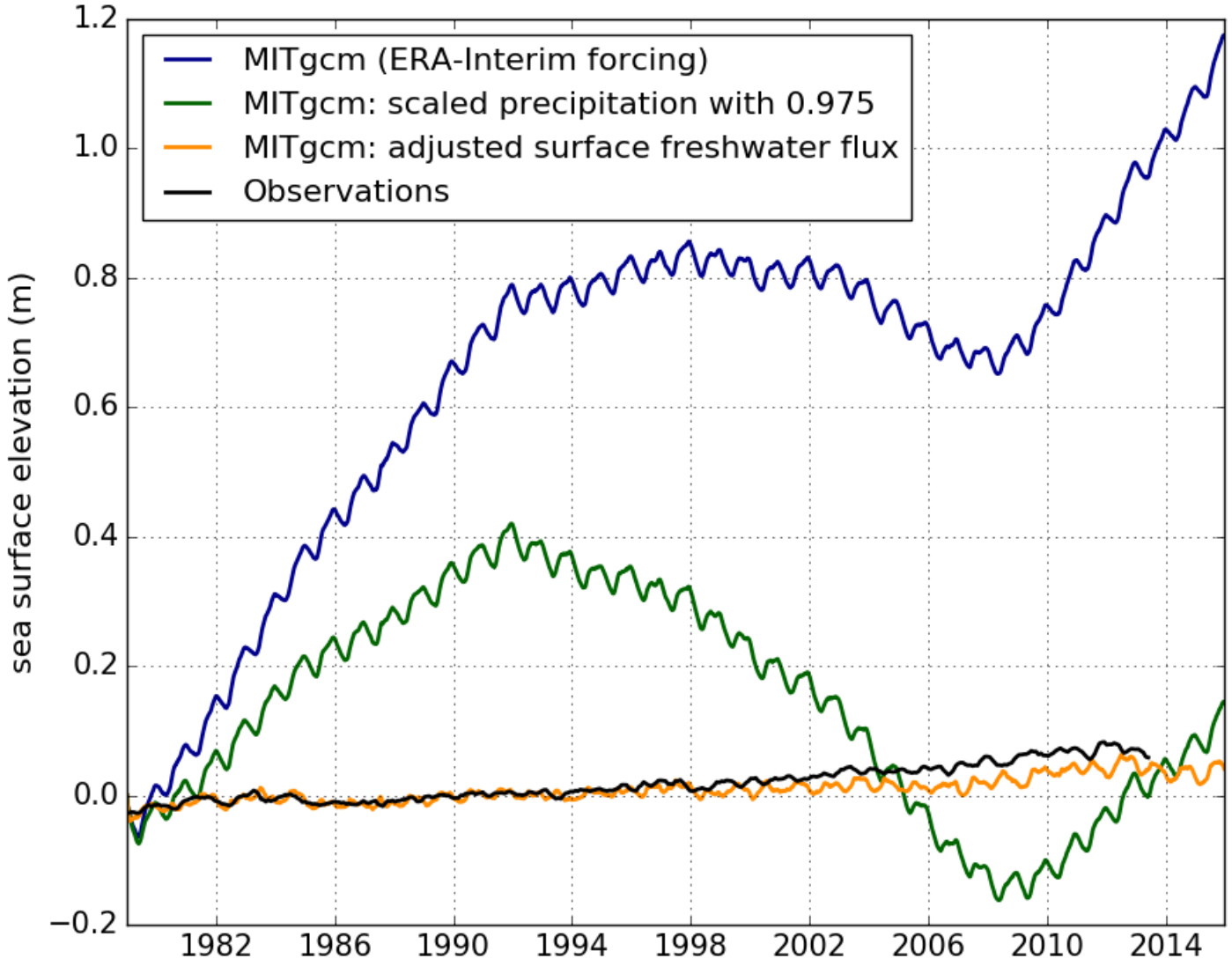


RMSE between densified time series and in-situ is 0.49 m

AWI - Introduction

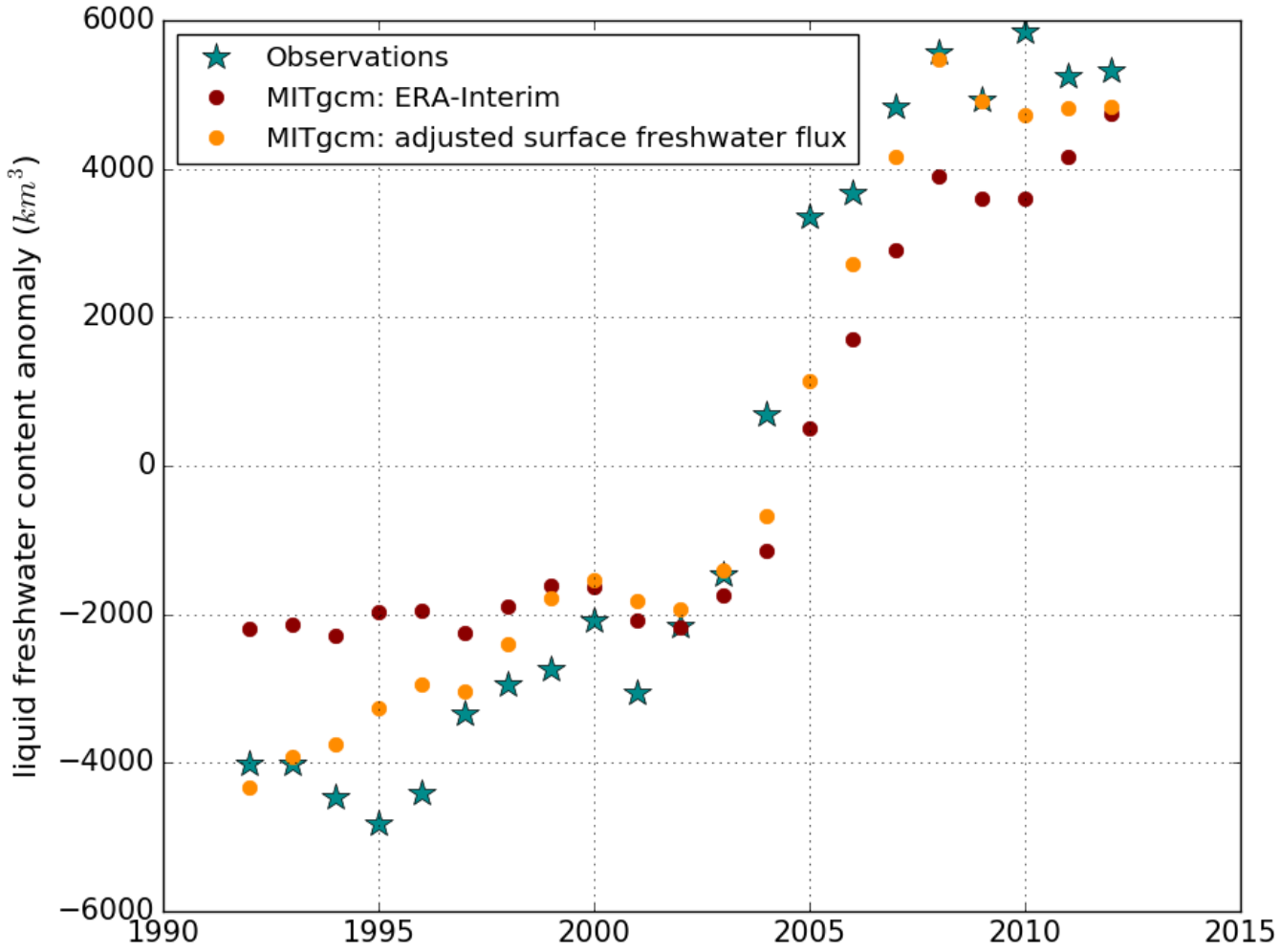
- Global simulations with analysis focus on Arctic
- Lat-lon-cap (llc) grid with nominally 1° resolution (40km in Arctic), 50 vertical layers
- Forward sensitivity experiments: force model with different run-off data sets to explore the effect of improved run-off data
- Prototype simulation with climatological seasonal run-off vs. interannual run-off in preparation for improved run-off data

Methods to adjust freshwater flux



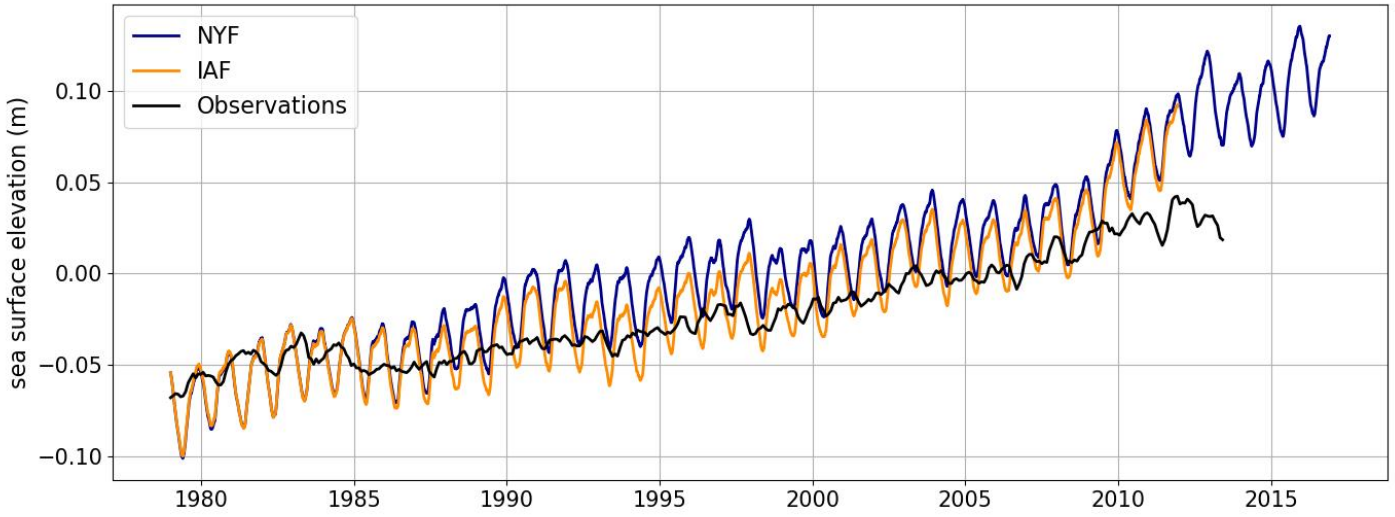
$$\text{freshwater budget} = E - (P + \Delta FW) - R$$

Comparison to observations

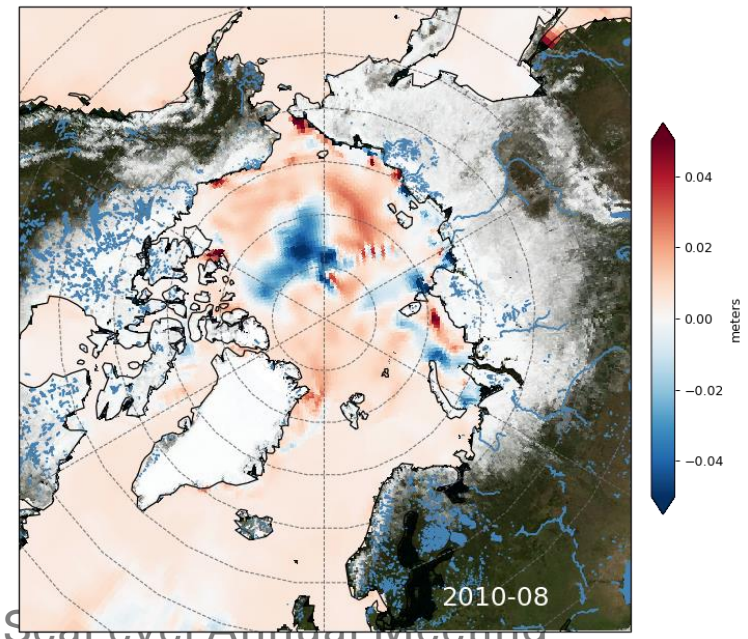


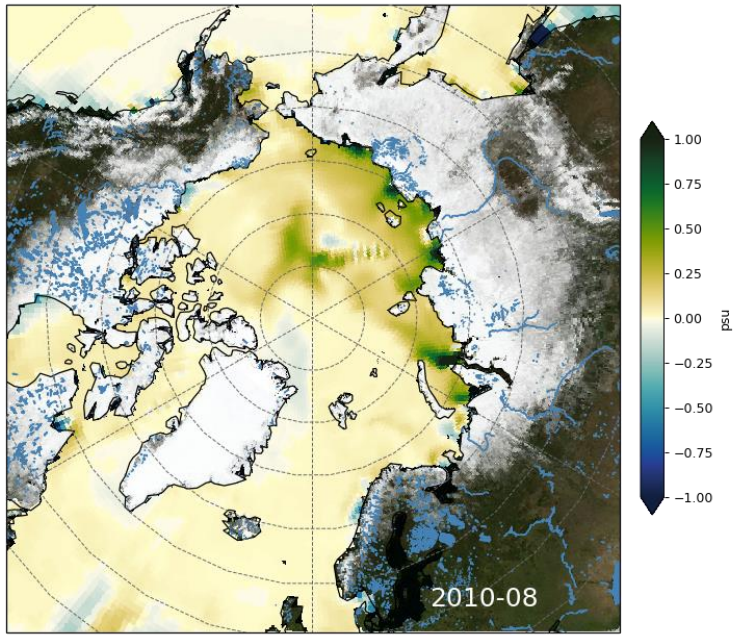
Observations: Rabe et al. 2014, Arctic Ocean basin liquid freshwater storage trend 1992–2012, Geophysical Research Letters

Results: climatology vs. interannual runoff



(Church and White, 2011)





CORE II datasets

Aug 2010: sea level differences are small but salinity difference have accumulated over time.

Conclusions

GIS

- First densification tests show motivating results
- Conducting LSC in time *and* space
- Include long -/no – repeat altimetry missions like CryoSat-2

AWI

- Insufficient freshwater forcing data sets require adjustment.
- Not yet addressed:
  higher resolution (1/3°) and adjoint simulations

Thank you very much for your attention!

Reference

- Church, J. A. and White, N. J. (2011). Sea-level rise from the late 19th to the early 21st century. Surveys in Geophys., 32(4-5):585–602.
- Holmes, R. M., A. I Shiklomanov, S. E. Tank, J.W. McClelland, and M. Tretiakov, 2015: River Discharge, https://www.arctic.noaa.gov/Report-Card.
- Rabe, B., Karcher, M., Kauker, F., Schauer, U., Toole, J. M., Krishfield, R. A., Pisarev, S., Kikuchi, T., and Su, J., 2014, Arctic Ocean basin liquid freshwater storage trend 1992–2012, Geophys. Res. Le., 41:961–968.