



Towards Estimating High-Resolution Ice Mass Changes from GRACE-FO Range Measurements

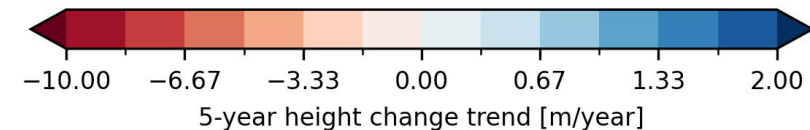
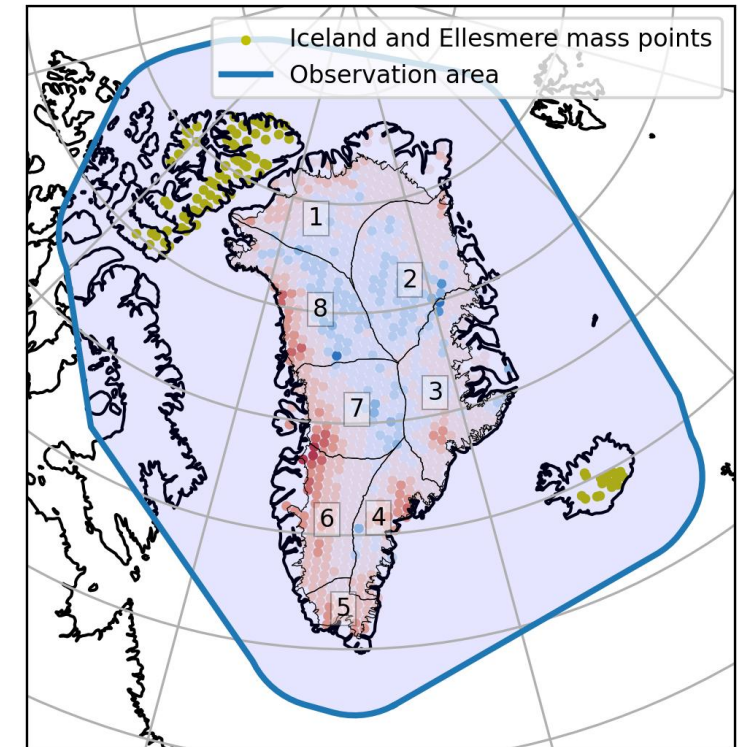
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Research Questions

- Can we use the range acceleration data from LRI to estimate sub-monthly ice mass change for Greenland?
- Does including height change trends from CryoSat-2 improve spatial resolution of these ice mass change estimates?
- Is it possible to estimate ice mass changes for the glaciers in Iceland using this method?

Method: prerequisites

- reference range accelerations from estimated orbits (GROOPS) to get residual range accelerations,
- a filter to reduce residual range accelerations to line-of-sight gravity differences (LGD) (Ghobadi-Far et al., 2018),
- LGD from monthly Level 2 gravity fields (ITSG2018),
- a GIA correction (Caron et al., 2018), and
- a regularisation scheme tailored to the study area.



Method: LGD from LRI

Residual range acceleration

Relative velocity vector
from dynamic orbit fit

Unit vector in the Line-
of-sight direction

$$\delta\ddot{\rho}(t) = \ddot{\rho}_{LRI}(t) - \frac{d}{dt} \left(\dot{\vec{x}}_{12}(t) \cdot \vec{e}_{12}(t) \right) = \delta g_{12}^{LOS}(t) + \Delta_0(t)$$

Line-of-sight gravity
difference (LGD)

Filtered out using the transfer
function by (Ghobadi-Far et al.,
2018)

Method: mass change from LGD

- Observation equation using point-mass approach

$$\delta g^{LOS}(t) = (\delta \ddot{\vec{x}}_1(t) - \delta \ddot{\vec{x}}_2(t)) \vec{e}_{12}(t),$$

with

$$\delta \ddot{\vec{x}}_i(t) = G \sum_j \frac{\delta m_j}{d_{ij}^3(t)} (\vec{x}_i(t) - \vec{x}_j(t)) + \delta \ddot{\vec{x}}_{ij}^{Loading}(t),$$

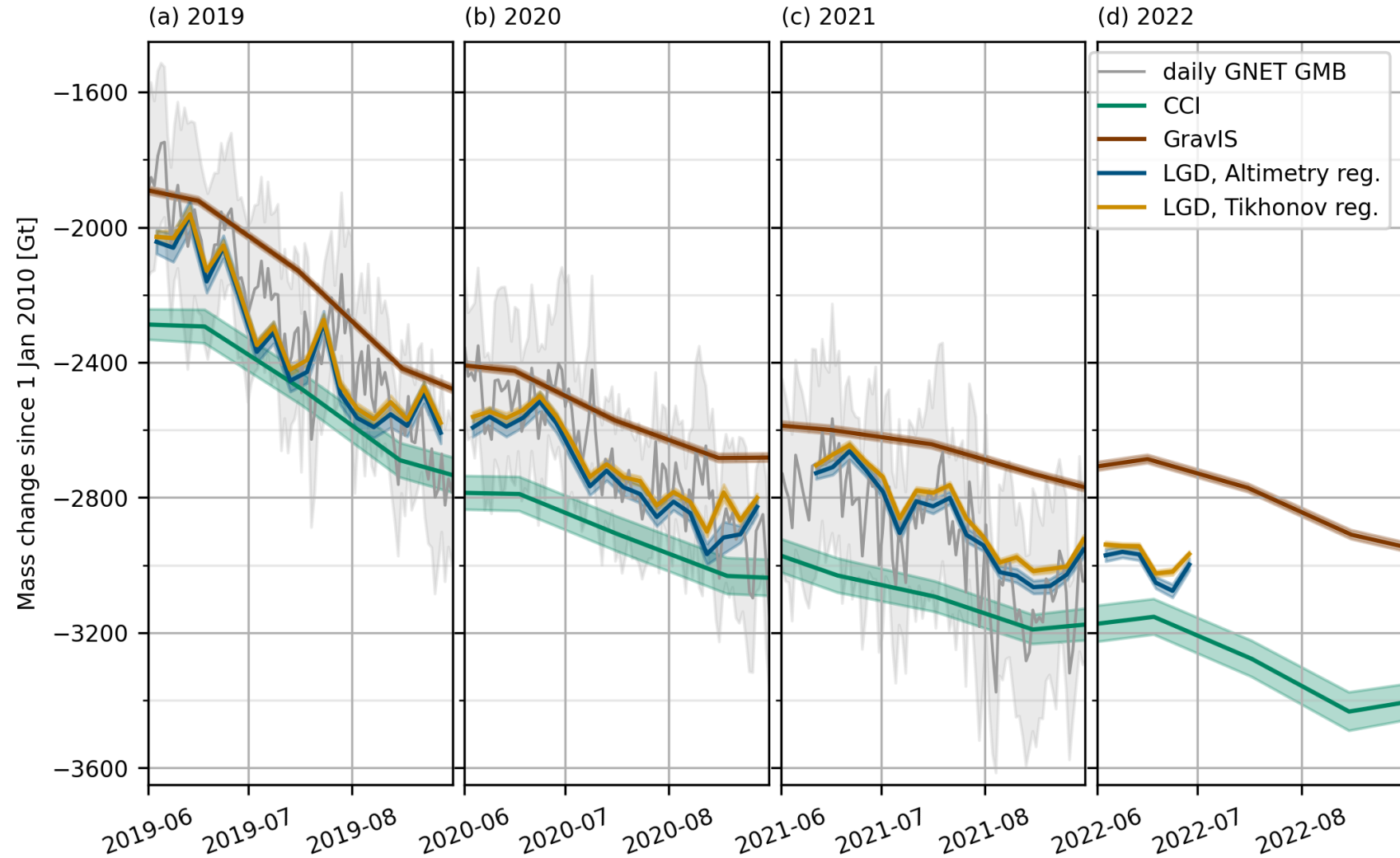
- Least-square adjustment using regularisation

$$\delta \mathbf{m} = (\mathbf{A}^T \mathbf{A} + \lambda_{alt} \mathbf{H}^T \mathbf{H} + \lambda_{Tik} \mathbf{I}) \delta \mathbf{g}^{LOS}$$

$$\mathbf{H}_{j,j} = \frac{\sqrt{\max |\mathbf{h}^{alt}|}}{|\mathbf{h}^{alt}|_j}$$

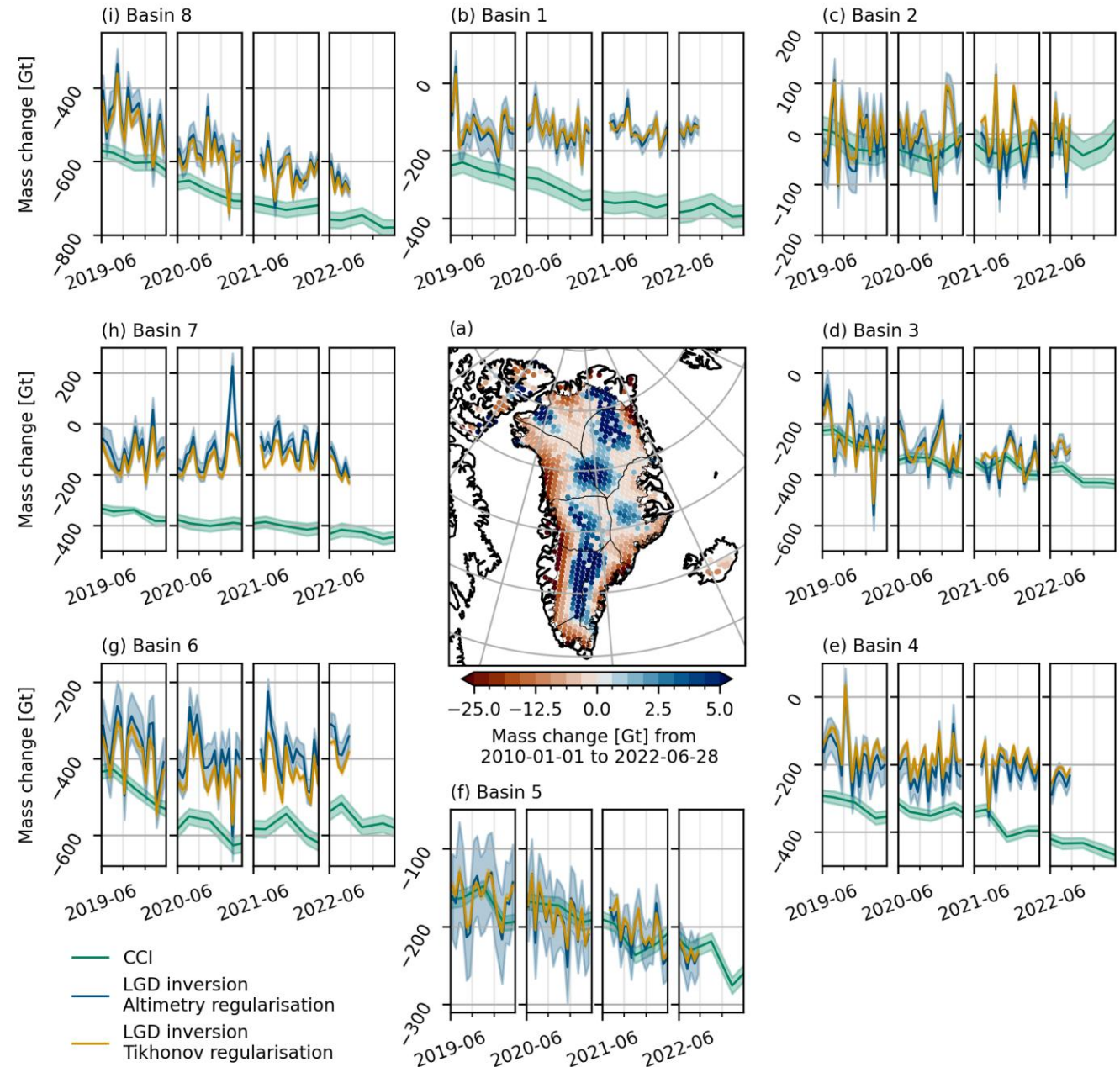
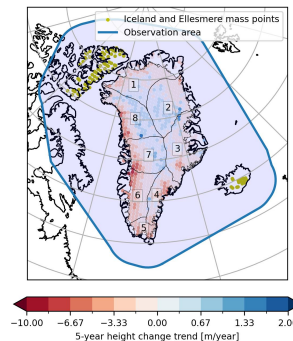
Results: Greenland

- Agrees well with comparison time-series by CCI (Barletta et al., 2020) and GravIS (Sasgen et al. 2020)
- Shows similar sub-monthly behaviour as a daily GNET GMB (Barletta et al., 2024)



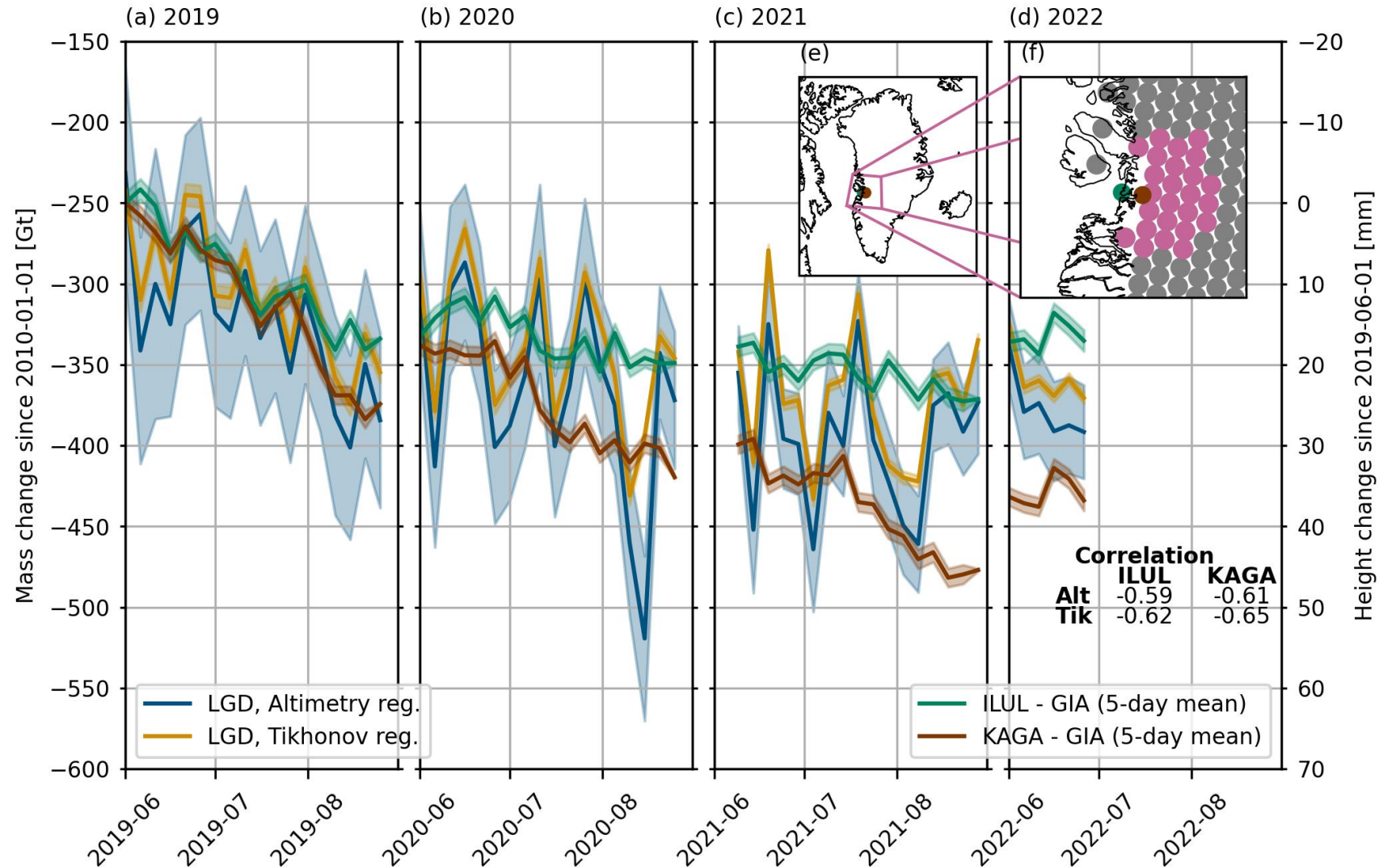
Results: Greenland

- Clear fingerprint of the altimetry data
- Small differences between the two regularisation schemes
- Generally lower mass loss estimates than reference monthly mass estimates by CCI
- Possible explanation: leakage due to observation area

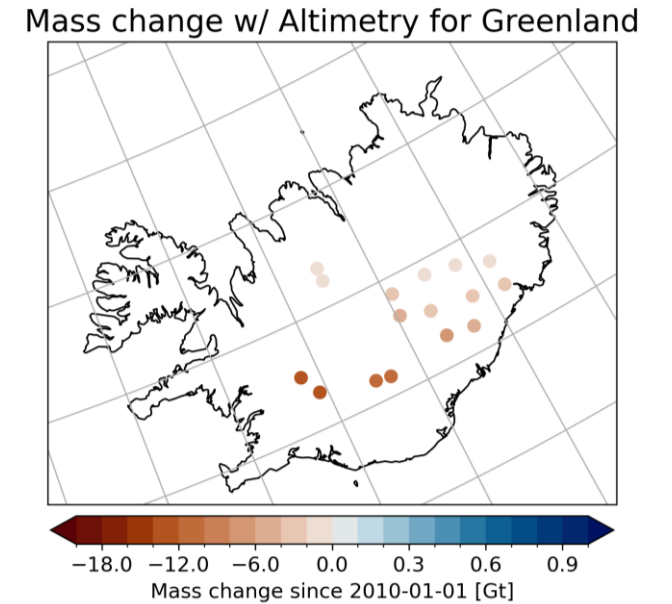
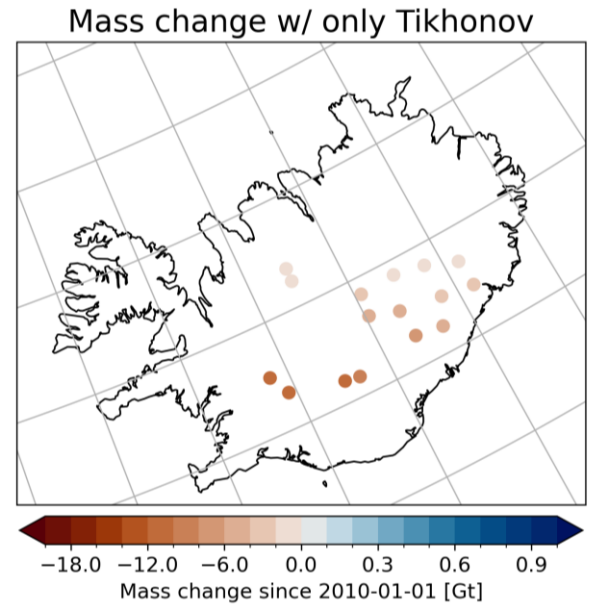
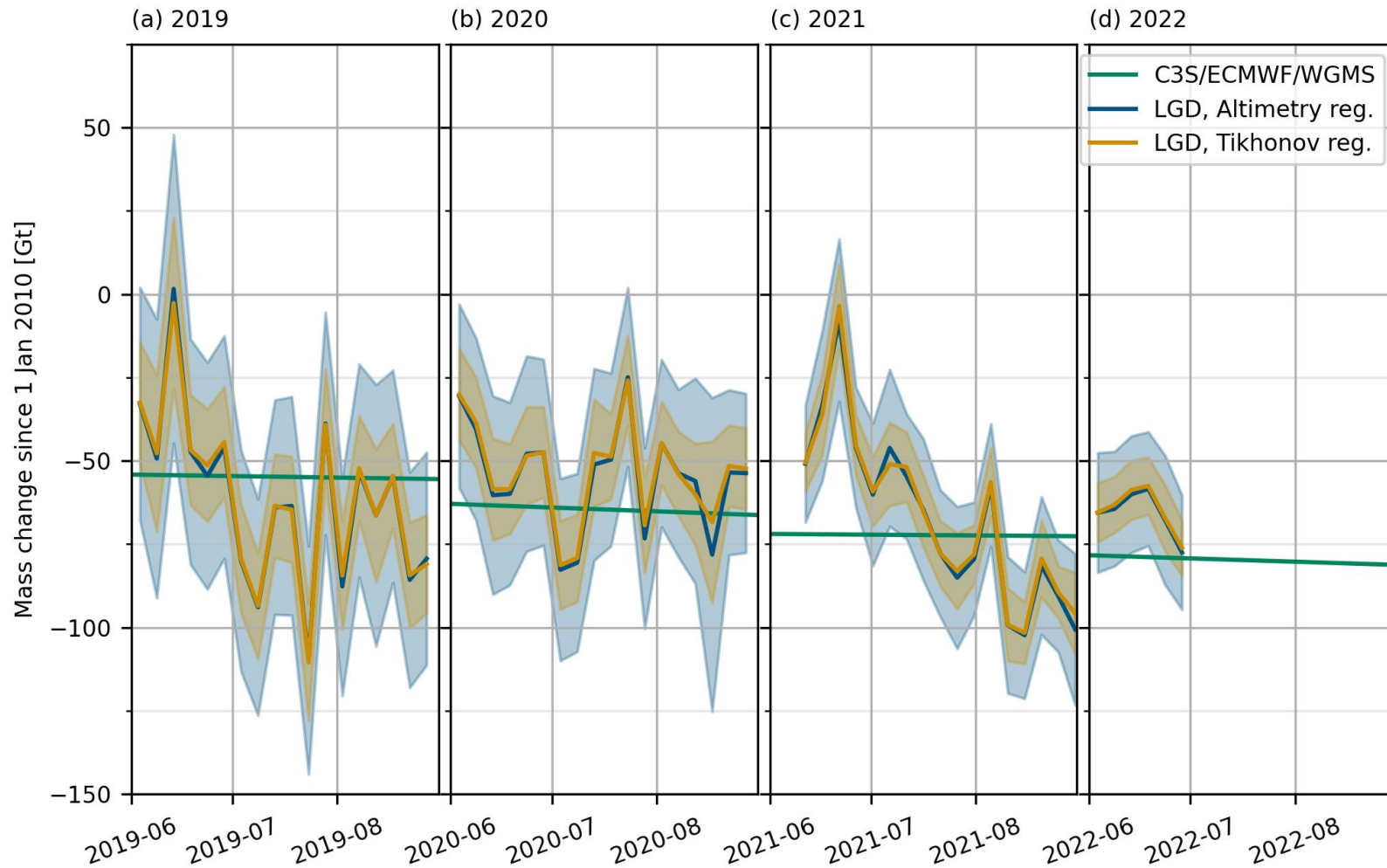


Results: Greenland

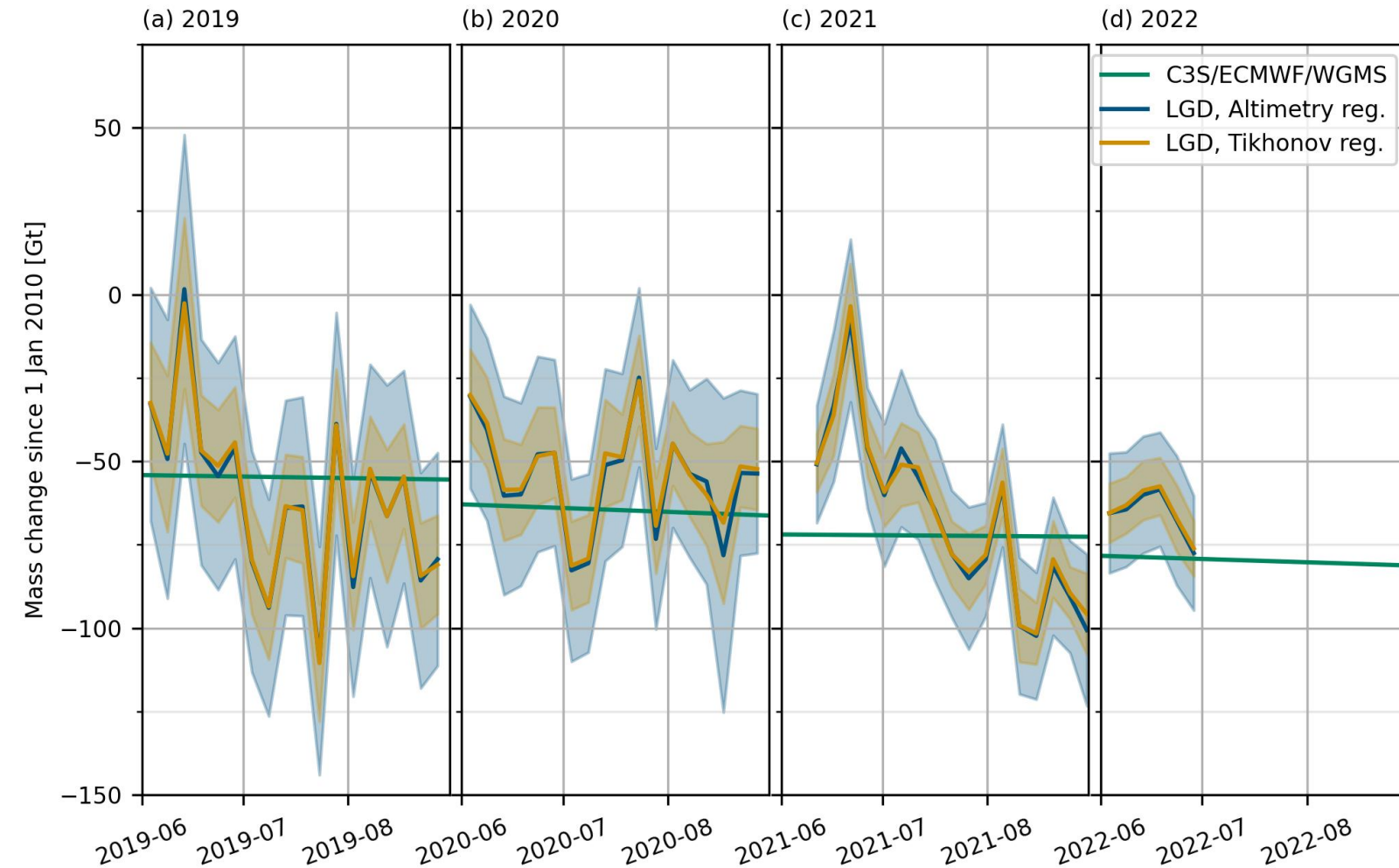
- Shows a moderate negative correlation (~ -0.6) with GNET uplift data by Solgaard et al., 2026
- Solution with altimetry regularisation shows higher mass loss



Results: Iceland



Results: Iceland



- Agrees in amplitude with the European state of the climate report 2025
- Currently no comparison to other data to confirm sub-monthly mass change

Reach out! 😊

Conclusions and Outlook

- *Can we use the range acceleration data from LRI to estimate sub-monthly ice mass change for Greenland?*

Yes, we can estimate 5-day mass change for the GrIS. But can we go down to daily mass change estimates?

- *Does including altimetry data improve spatial resolution of these ice mass change estimates?*

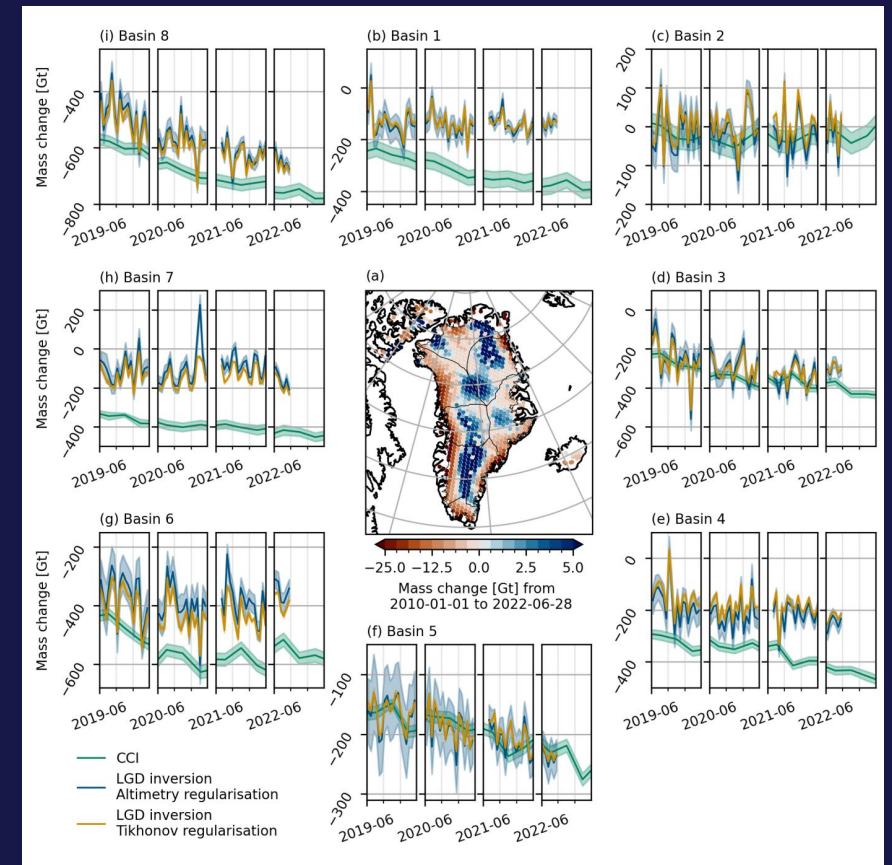
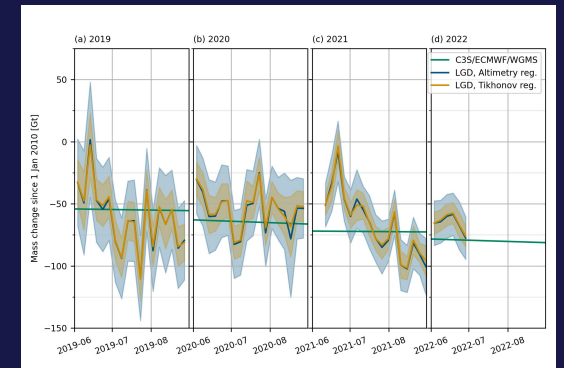
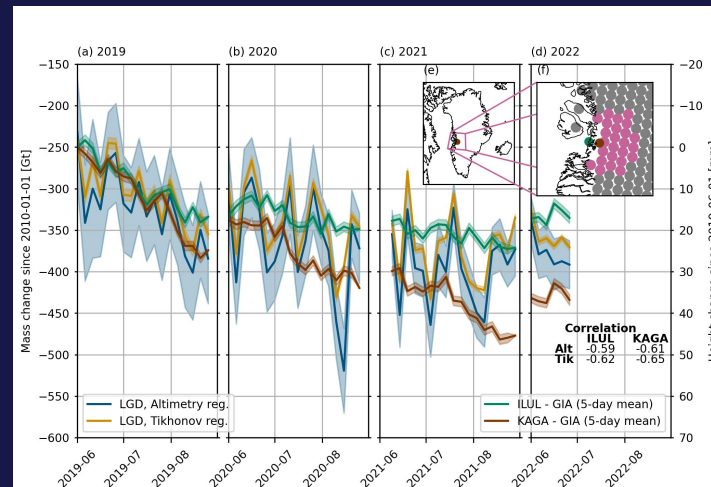
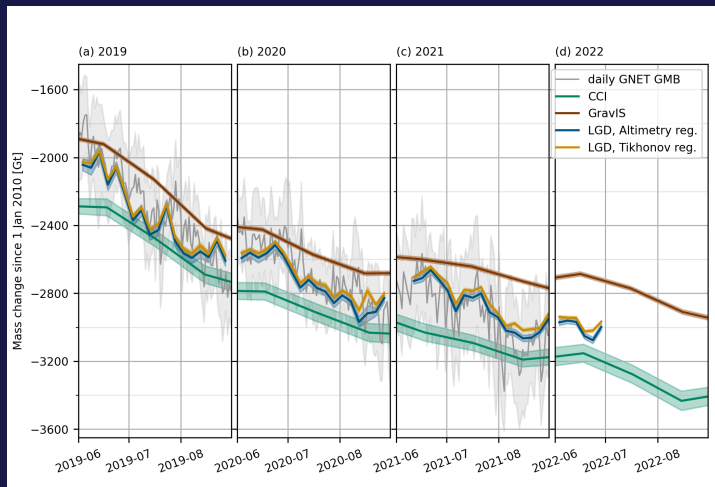
Not necessarily. Comparison to GNET stations shows no clear improvement when looking at sub-basin scale.

- *Is it possible to estimate ice mass changes for the glaciers in Iceland using this method?*

Maybe. The mean mass change for Iceland is of the expected magnitude but comparison to other independent data is needed to check the sub-yearly signal.

Thanks!

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Orbit estimation: models

Data	Potential Models	
initial orbit	GNV1B	AOD1B RL07
satellite attitude	SCA1B	GOCO06s (d/o 0-300)
intersatellite ranging	KBR1B	IERS 2010
non-gravitational forces	ACT1B and THR1B	FES2014b
		TiME22
Other		Mean Pole
earth rotation	IAU2000	Desai 2004
ephemerides	JPL DE432	

Error estimation: apriori and a posteriori

Standard deviations of the residuals for LGD from the monthly field and the two different regularisations.

	2019	2020	2021	2022
σ_{monthly}	5.11 nm/s ²	4.04 nm/s ²	2.90 nm/s ²	2.78 nm/s ²
$\sigma^{\text{altimetry}}$	5.12 nm/s ²	4.09 nm/s ²	3.41 nm/s ²	3.28 nm/s ²
σ^{Tikhonov}	5.13 nm/s ²	4.12 nm/s ²	3.45 nm/s ²	3.30 nm/s ²

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