INDICATION OF GLACIALLY-INDUCED FAULT REACTIVATION IN LATVIA, LITHUANIA AND THE KALININGRAD DISTRICT OF RUSSIA FROM MODELS OF GLACIAL ISOSTATIC ADJUSTMENT

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- Geological investigations presented soft-sediment deformation structures (SSDS) in a few outcrops. Glacial isostatic adjustment (GIA)-triggered earthquakes at pre-existing faults are among others discussed as sources for SSDS generation.
- We use established GIA models to investigate if GIA can be considered at each location.
- We apply the Coulomb Failure Stress for a critically-stressed crust which eases identification of potential GIA influence with a threshold value.
- Modelling results support findings in some outcrops, while for others they exclude GIA as source.
- Potential mutual benefit of geological and modelling investigations is demonstrated.
- Corresponding paper has been published in Baltica.
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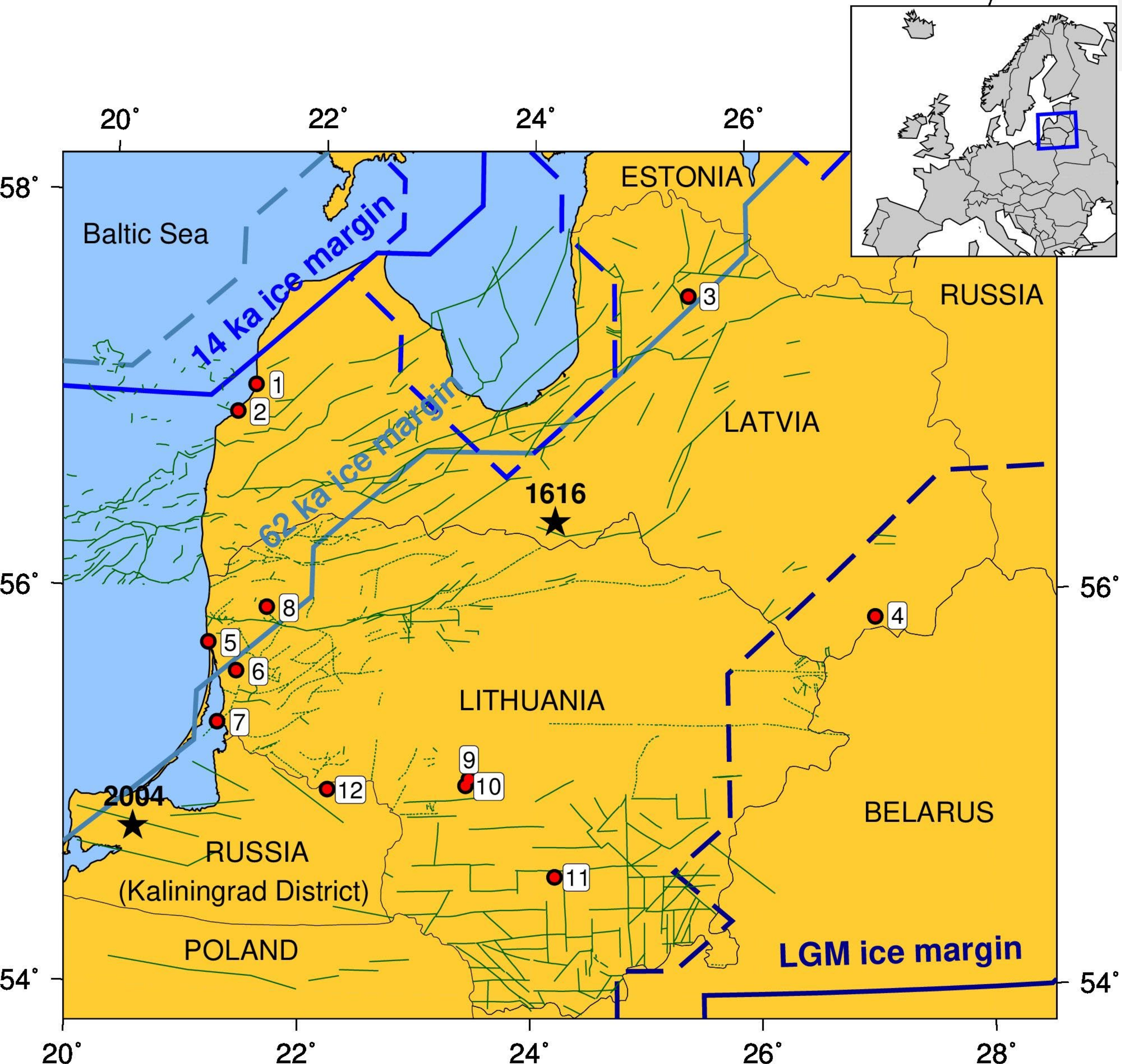
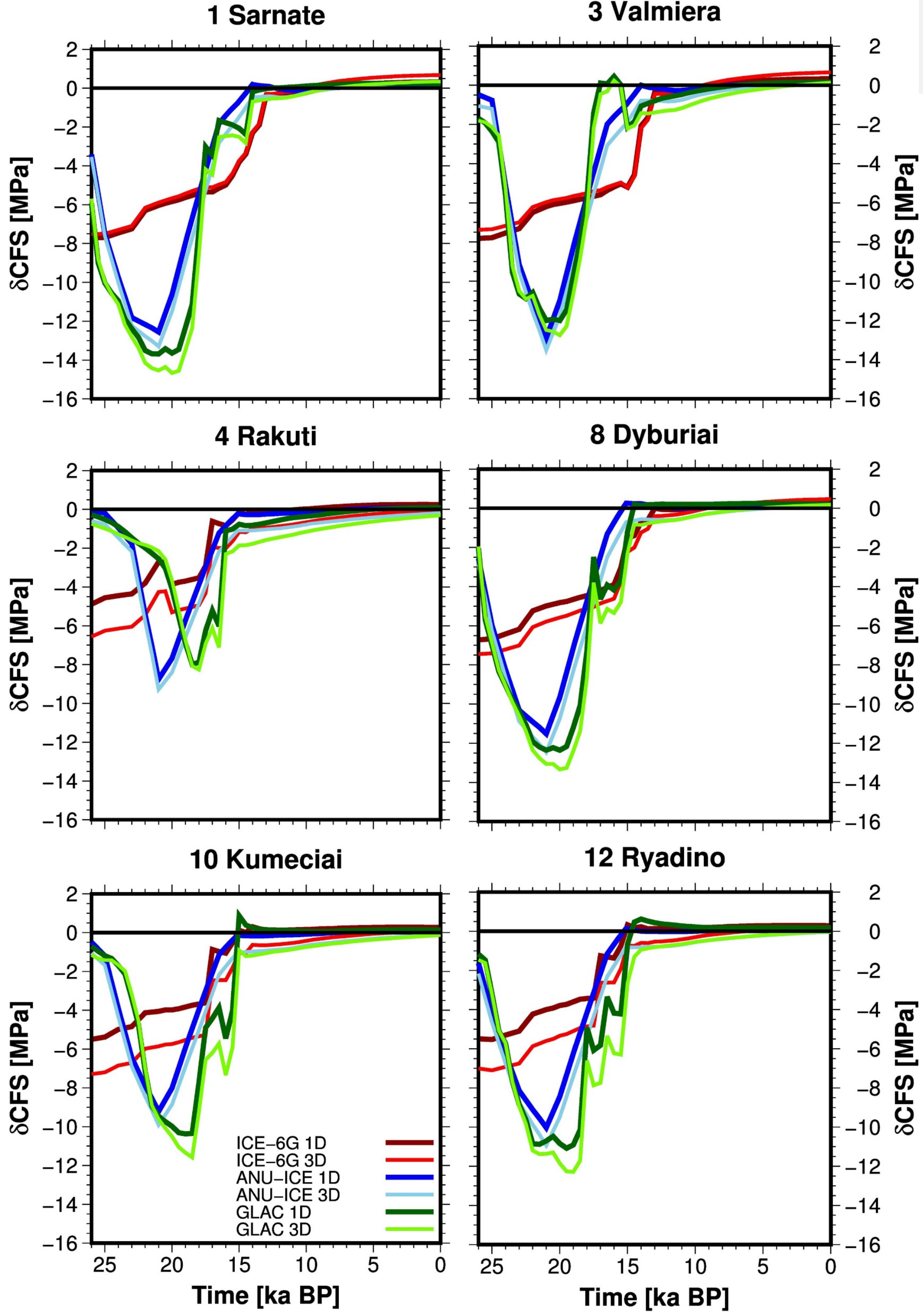


Locations (red dots) with SSDS (1–4, 6–12) and the Giruliai mega-landslide (5). More info on next slide.

Dark green lines: Tectonic faults in the Caledonian structural complex after Ņikuļins (2011, 2019) for Latvia, updated after Čyžienė et al. (2007) for Lithuania and after Sharov et al. (2007) for Poland and the Kaliningrad District. Black stars: epicentres of the 1616 Latvia and 2004 Kaliningrad earthquakes. Bluish lines represent ice limits from models of the Weichselian glaciation, whereas solid is model ANU-ICE (Lambeck et al. 2010) and dashed is model GLAC (Tarasov 2013). Dark blue is limit at Last Glacial Maximum (LGM), common blue at 14 ka, and light blue at 62 ka.

Location	#	Brief description	Timing information	Reference
Sārnate, LV	1	Lake or lagoon environment. SSDS in two units with hiatus, likely one single event, palaeoseismic event possible	Ice-free ca. 14.0 ka, age of organic deposits 7.73 ka and younger	Nartišs et al. (2018)
Baltmuiža, LV	2	Lacustrine sediments with 3 SSDS horizons, palaeoseismic event possible	Deposition 28.6–23.4 ka, ice-free ca. 14.0 ka	Belzyt et al. (2018a)
Valmiera, LV	3	Glaciofluvial sediments, palaeoseismic event very likely	Deposition <14.5 ka	Van Loon et al. (2016)
Rakuti, LV	4	Glaciolacustrine sediments, palaeoseismic event very likely	Deposition 17.0–16.0 ka	Van Loon et al. (2016)
Giruliai mega-landslide, LT	5	360 m long mea-landslide, hypothetically triggered by earthquake	Happened 7.7 ka or any time thereafter	Damušytė, Bitinas (2018), Bitinas et al. (2016)
Juodikiai, LT	6	Glaciofluvial delta with SSDS, not further investigated	Not available (Late Weichselian)	Bitinas, Damušytė (2018)
Ventės Ragas, LT	7	Sandy lacustrine and aeolian sediments with SSDS, not further investigated	Not available (Late Weichselian)	Bitinas, Damušytė (2018)
Dyburiai, LT	8	Glaciolacustrine inter-moraine sediments, palaeoseismic event very likely	Deposition 119.7–91.1 ka, ages subject to debate	Pisarska- Jamroży et al. (2018b)
Slinkis, LT	9	Meandering fluvial system sediments with trapped SSDS, palaeoseismic event or glacial earthquake suggested	Deposition 24.0–21.2 ka	Belzyt et al. (2018b), Pisarska- Jamroży et al. (2019)
Kumečiai, LT	10	Fluvial meandering system sediments with several layers of SSDS, palaeoseismic event unlikely	Deposition 76.0–46.7 ka, ages subject to debate	Pisarska- Jamroży et al. (2018c)
Liciškėnai, LT	11	Glaciolacustrine sediments with SSDS, palaeoseismic event unlikely	Deposition 74.2–51.7 ka, ages subject to debate	Woronko et al. (2018)
Ryadino, RUS	12	Glaciolacustrine sediments with SSDS, palaeoseismic event likely	Deposition 8.7–7.5 ka	Druzhinina et al. (2017)

Changes in Coulomb Failure Stress (δCFS) for thrust-faulting tectonic background mechanism for the last 26 ka at 6 selected locations.

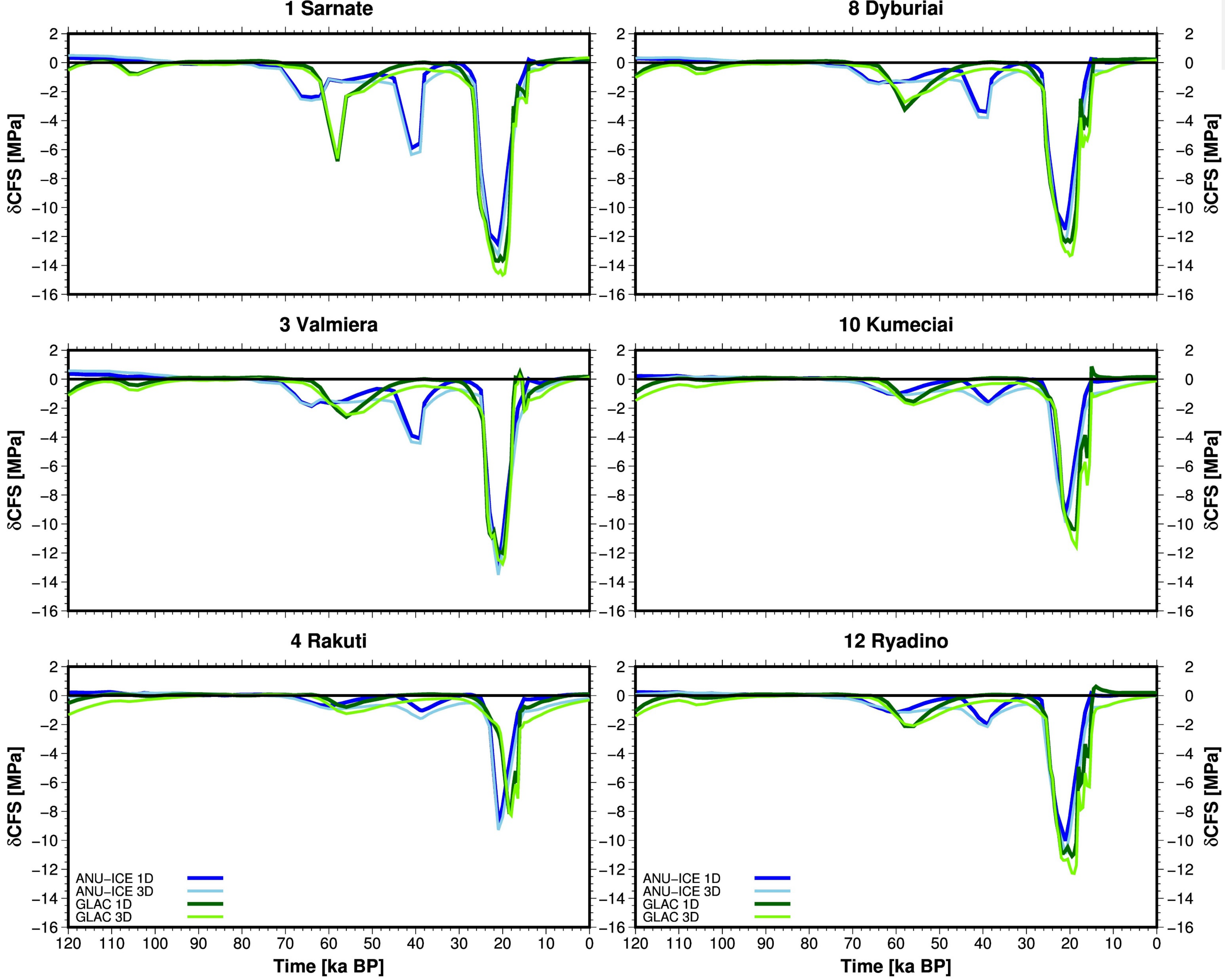


ICE-6G_C (red, Peltier et al. 2015), ANU-ICE (blue, Lambeck et al. 2010) and GLAC (green, Tarasov 2013) are used as ice load history models. The thicker, darker curves represent a 1D Earth model (properties vary with depth only) and the lighter, thinner curves a 3D Earth model (with lateral heterogeneities), which both roughly envelope the curves from 8 different GIA models we tested. δCFS is calculated at a depth of 12.5 km.

Black line at 0 MPa is the threshold. Negative values point to stability while positive values point to instability (earthquakes possible).

We assume faults are optimally oriented: their strike and dip values promote faulting for a commonly used friction coefficient of 0.6 and faults are perpendicular to the maximum horizontal direction of the tectonic background stress.

Pore-fluid pressure is not investigated.



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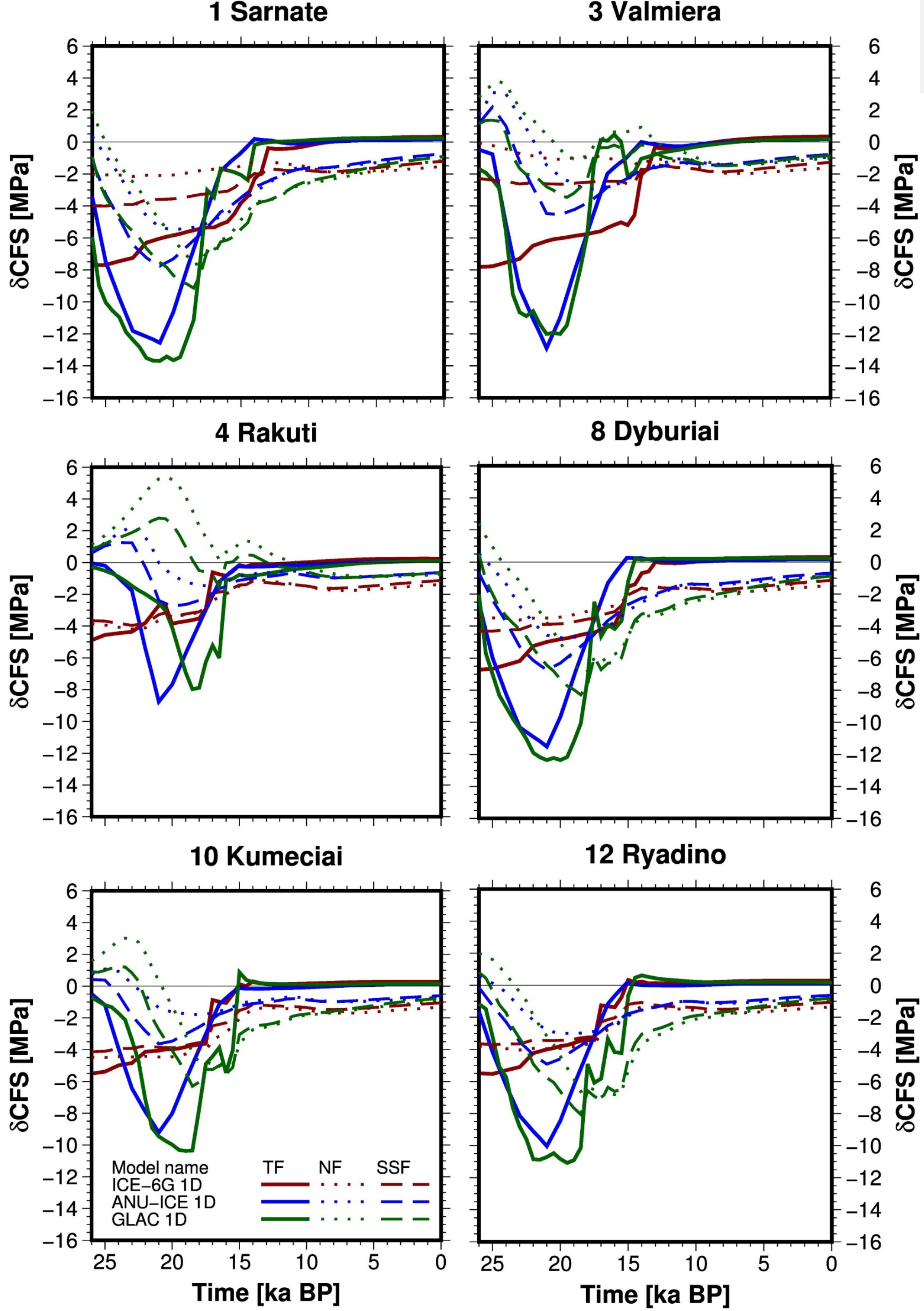
Changes in Coulomb Failure Stress (δCFS) for thrust-faulting tectonic background mechanism for the last 120 ka at 6 selected locations.

ICE-6G_C is not available for the longer time span.



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δCFS for thrust (solid), strike-slip (dashed) and normal (dotted) faulting mechanism for the last 26 ka at 6 selected locations.

The ice load history models are ICE-6G_C (red, Peltier et al. 2015), ANU-ICE (blue, Lambeck et al. 2010) and GLAC (green, Tarasov 2013). Only results for the 1D Earth model are shown. δCFS is calculated at a depth of 12.5 km.

CONCLUSIONS

- Within the stated assumptions, all locations reached at several points in time a state of fault instability, independent of the background stress regime and the chosen GIA model setup
- Based on the dating of SSDS horizons, GIA unlikely as source for Slinkis, Kumečiai and Liciškėnai
- But GIA likely at Sarnate, Valmiera, Rakuti, Dyburiai and Ryadino
- Behaviour of δCFS curves after 15 ka BP suggests that historic and recent earthquakes in the East Baltic area (see e.g., Ņikuļins 2011, Pačėsa, Šliaupa 2011) could be an aftermath of the last glaciation which has already been considered for Germany and Denmark (Brandes et al. 2015, 2019)
- If more SSDS are found and categorised as seismites, thorough dating of the deposition horizon can help in GIA modelling by excluding or supporting certain GIA model configurations; locations of glacially-induced faulting might serve as additional constraint on GIA modelling

For all references, please see corresponding publication.