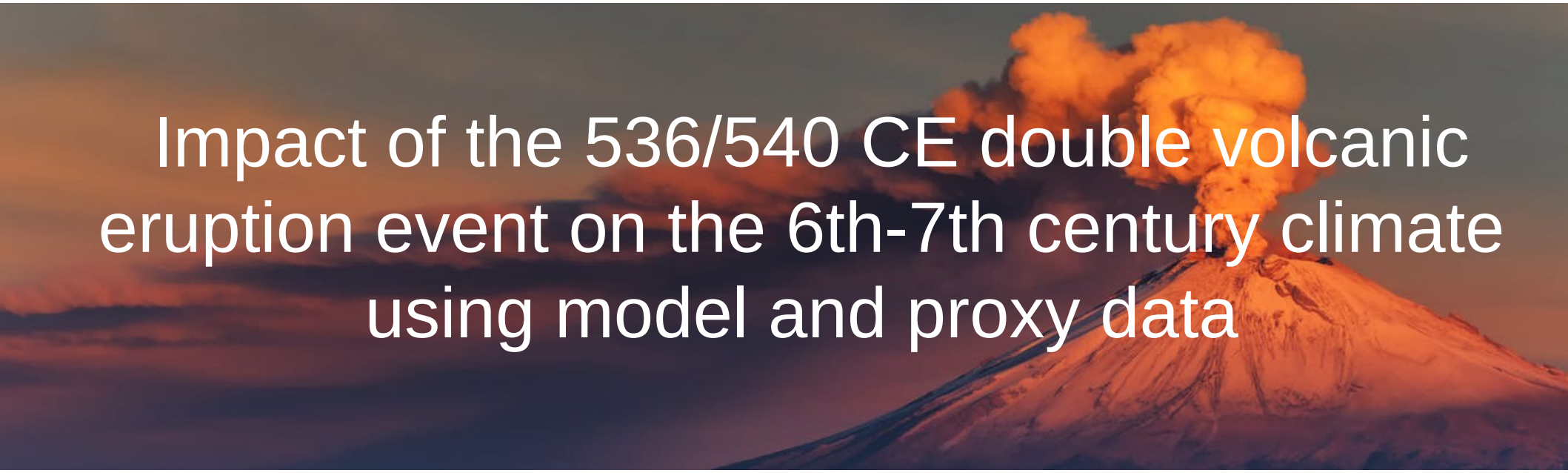

Impact of the 536/540 CE double volcanic eruption event on the 6th-7th century climate using model and proxy data

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Motivation and Background

- Volcanic eruptions are important climate drivers (Crowley et al., 2000; Robock 2000)
- Very cold period after the 536/540 CE double eruption event in the mid-6th century (Larsen et al., 2008; Sigl et al., 2015)
- Evidence from multiple tree-ring records for a centennial cooling up to 660 CE (Büntgen et al., 2016)
- Previous MPI-ESM simulations show a decrease in surface temperature and an increase in Arctic sea-ice up to 15 years (Toohey et al., 2016)

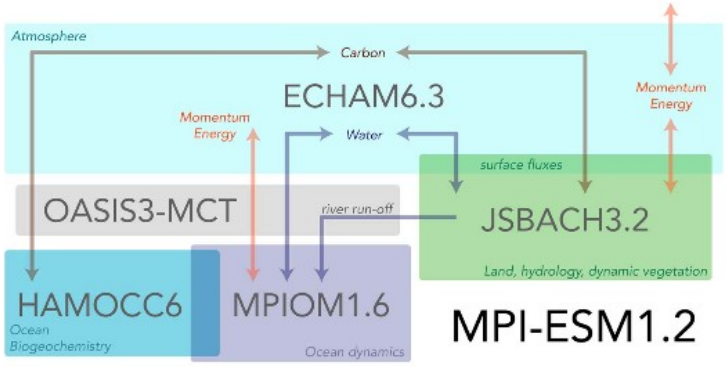
Research question:

Can we force a century long lasting cooling due to major volcanic eruptions in the 6th-7th century in earth system models?

Model experiment and set-up

- MPI-ESM-LR1.2 version for CMIP6/PMIP4 (Mauritsen et al., 2019)
- ECHAM6: T63 → 200x200 km, 47 vertical levels, top @ 80km
- MPIOM: GR1.5 → 150x150 km, 40 vertical levels
- 10 x 160 years → 520-680 CE
- spin up from PMIP4/Past2k run
- PMIP4 volcanic forcing

  (Toohey and Sigl 2017, Jungclaus et al., 2017)
- Anomalies calculated wrt 0-1850 CE (Past2k run)

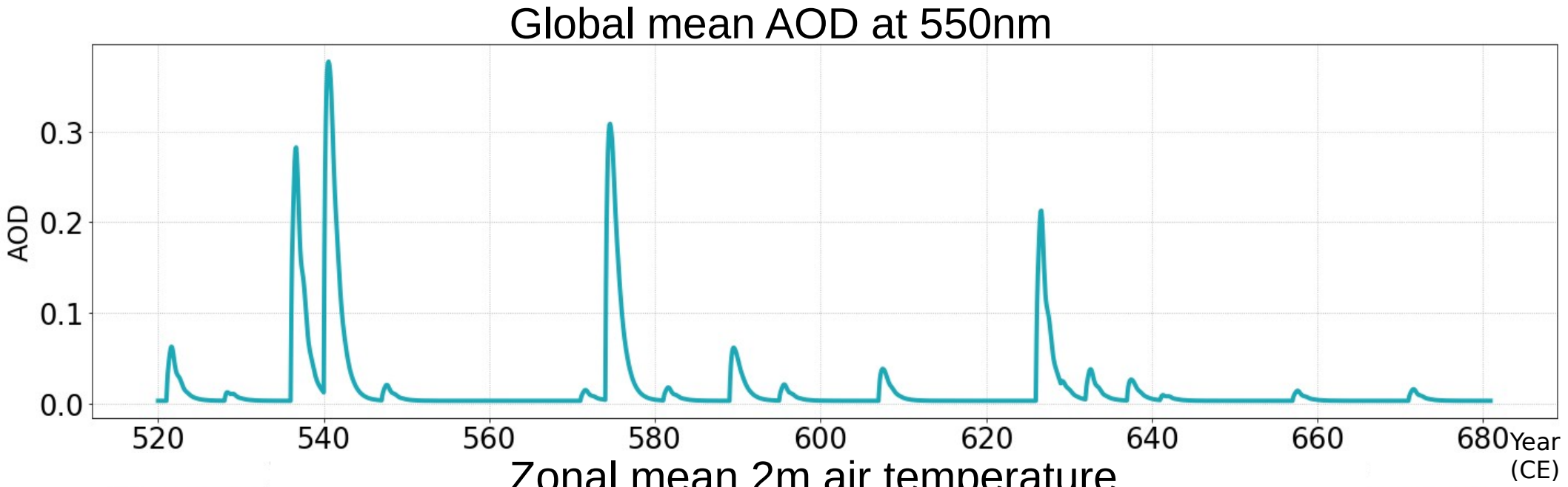


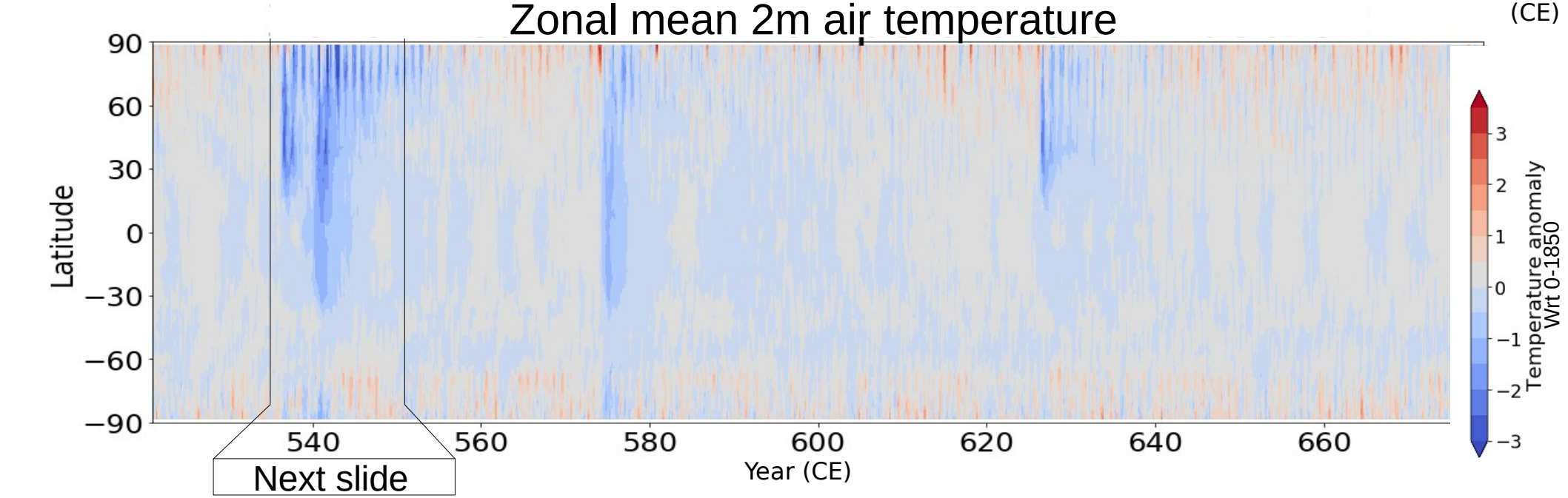
Mauritsen et al. (2019)

Eruption year CE	Eruption month	S injected	Peak aerosol optical depth in model	Latitude of eruption
536	Jan	18.8 Tg	0.5	NHext (~45N)
540	Jan	31.8 Tg	0.7	Tropical (~15N)
574	Jan	24.2 Tg	0.6	Tropical
626	Jan	13.2 Tg	0.4	NHext

*Toohey and Sigl (2017): eVolv2k, based on ice-core records + Easy Volcanic Aerosol model + scaling factor (Gao et al. 2006)

Volcanic forcing - temperature response





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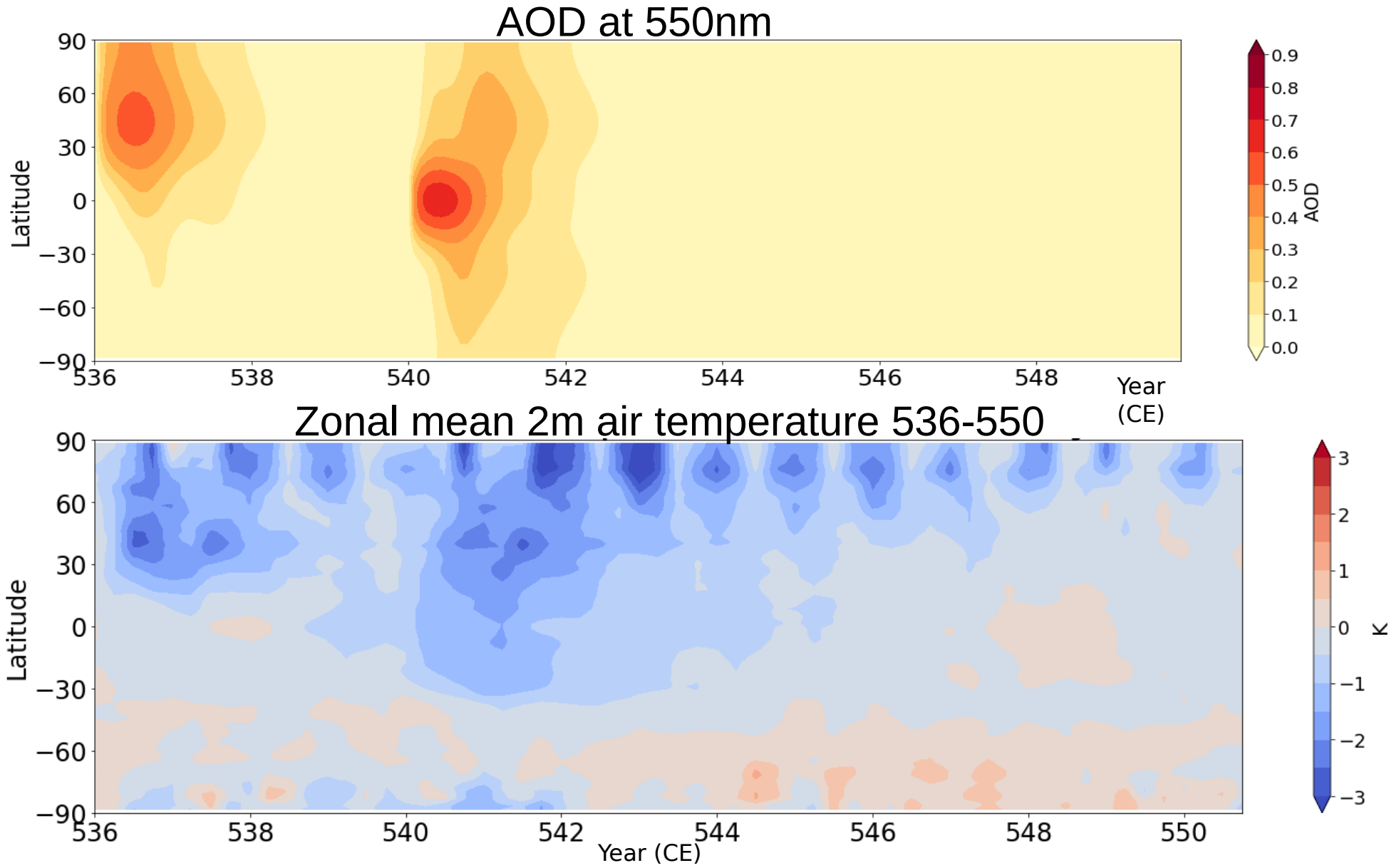
Volcanic forcing - temperature response



AOD disappears after ~2 years → temperature anomaly at high latitudes lasts longer ~20 years → ocean/sea-ice feedback?

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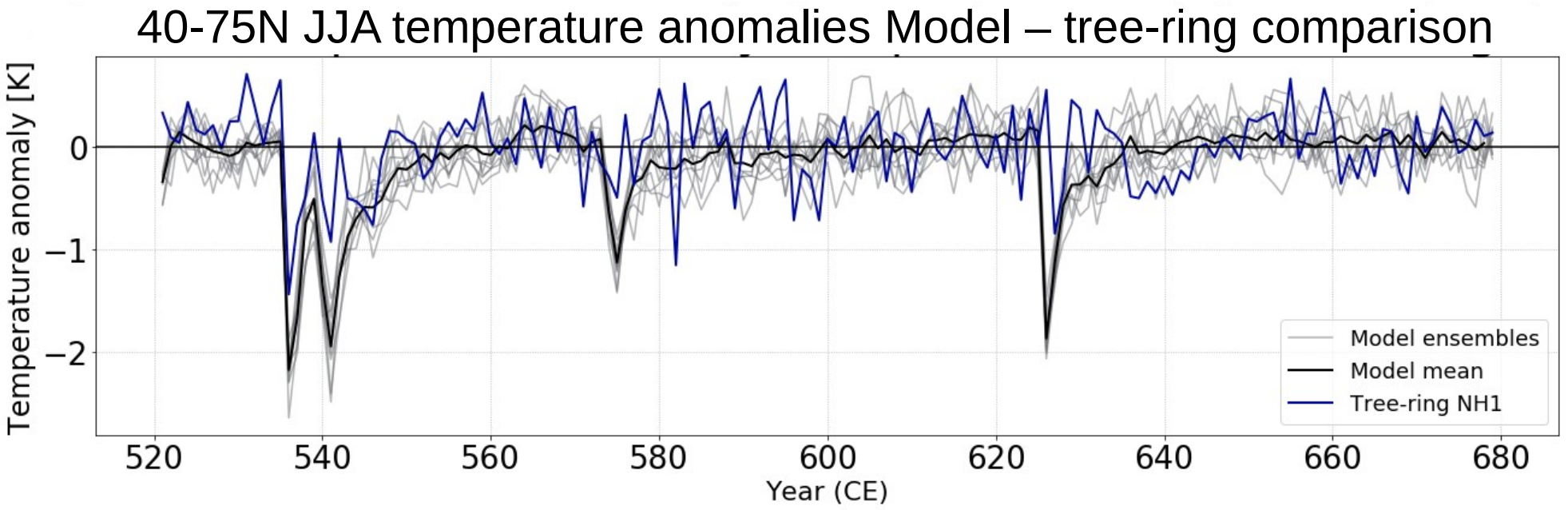
Northern Hemisphere temperature: Model – Tree-ring comparison

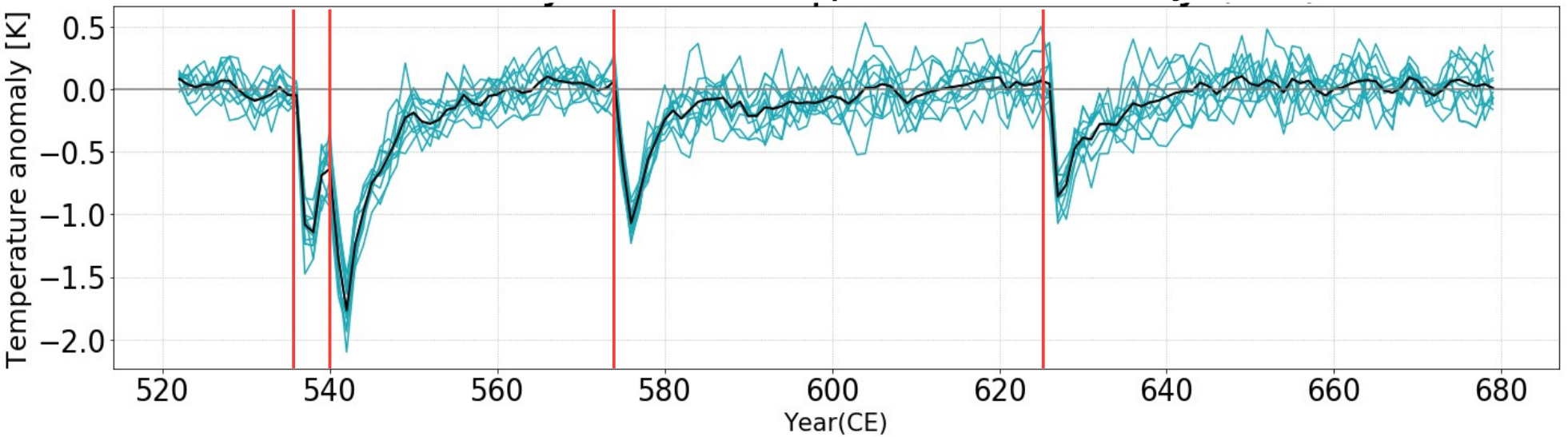


- Tree ring data from Stoffel et al. (2015)
- Anomalies wrt 1961-1990 → (NH1)
- Model data between 40-75N, land only
- JJA anomalies wrt Past2k (0-1850 CE)

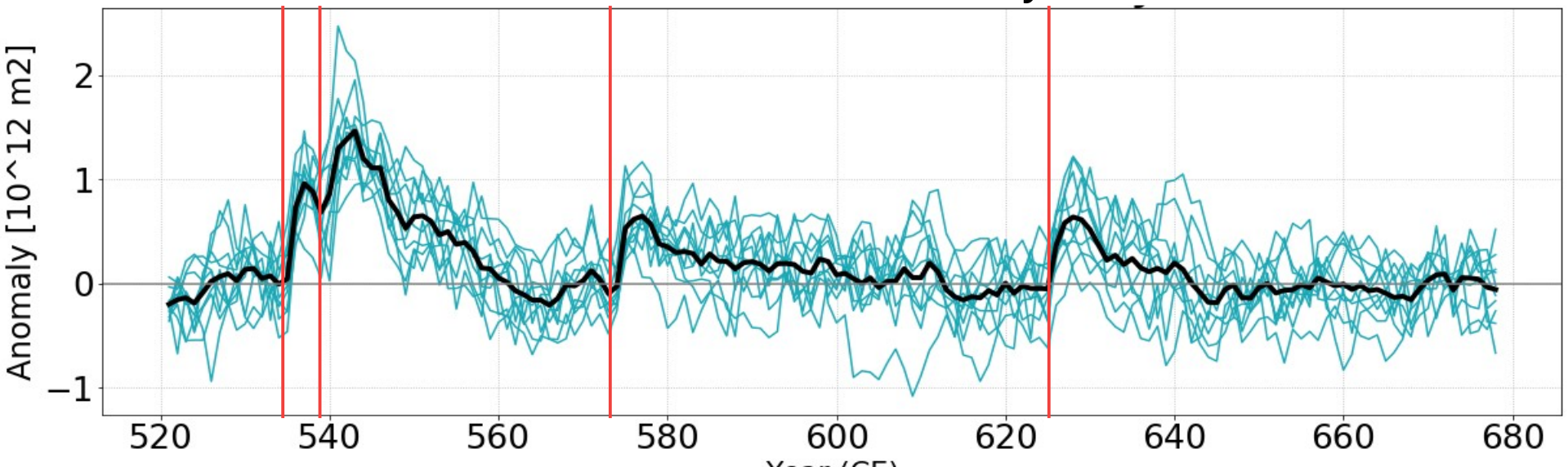
Good agreement between model simulations and tree-ring data
~20 year cooling after eruptions

NH 2m temperature and sea-ice cover

NH mean 2m air temperature anomaly



NH sea-ice area anomaly



Sea-ice and temperature anomalies correspond very well, with the same recovery time

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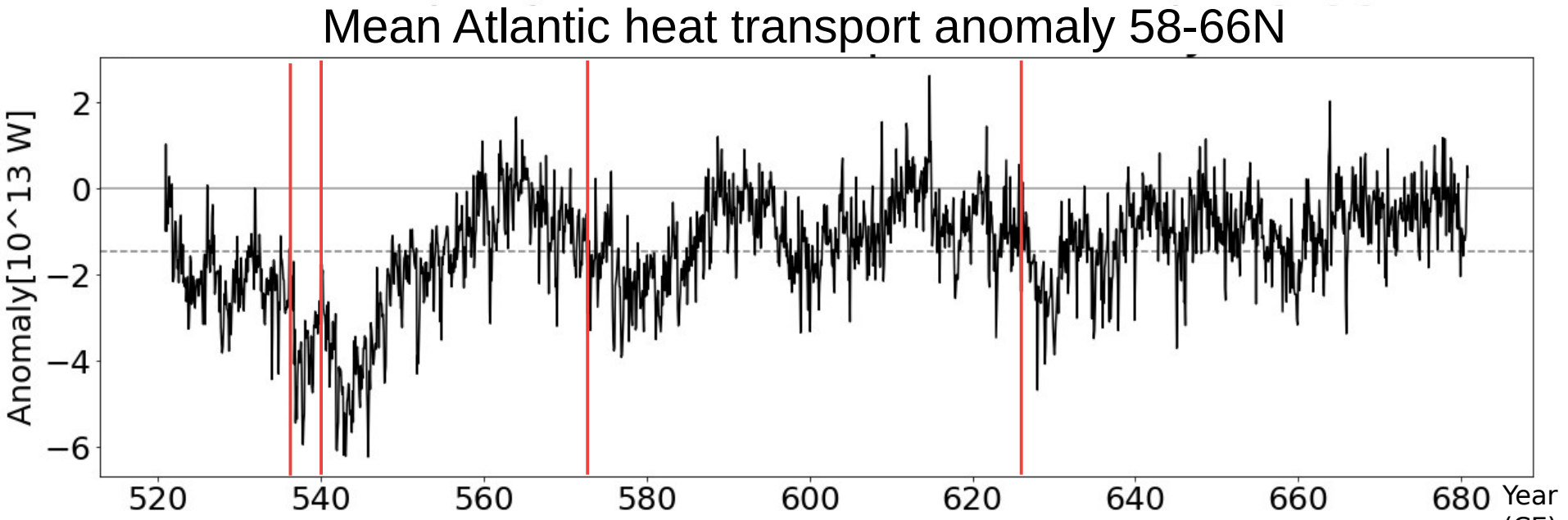
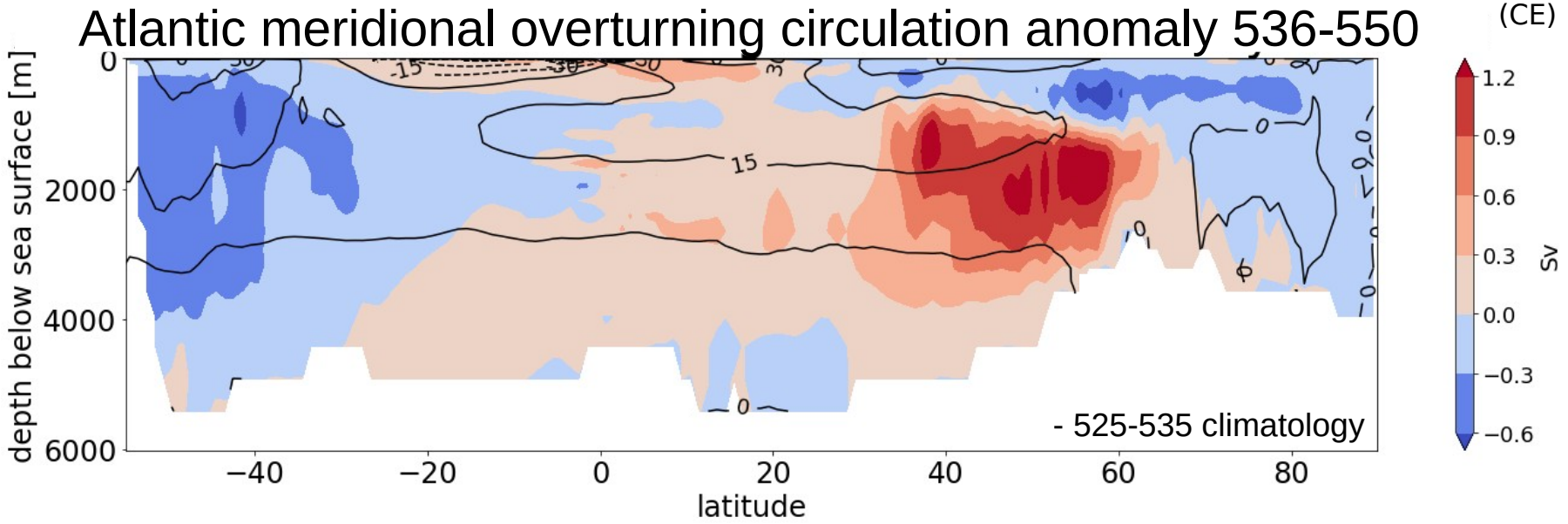
Ocean heat transport and circulation





Reduced northward heat transport after the eruptions (top figure) → decadal variability
Enhanced Atlantic meridional overturning circulation @ ~40-60N (bottom figure)

van Dijk et al., in prep.

Summary

New model simulations using the MPI-ESM1.2 using the PMIP4 volcanic forcing for 520-680 CE reveal that:

- Modeled surface temperature response lasts up to 20 years, longer than the prescribed volcanic forcing (2-3 years)
- MPI-ESM runs capture the tree-ring proxy temperature anomalies well
- Ocean – sea-ice feedbacks lead to a prolonged surface climate response
- Ocean heat transport shows a decadal variability with eruptions superimposed on top
- The Atlantic meridional overturning circulation is enhanced after the 536/540 CE double volcanic eruption event