The codependence of contributors to regional sea-level rise

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Motivation

- Impact analysis of sea-level rise is commonly based on projections of **regional** sea-level rise
- The uncertainty in climate projections is often derived from model **variance**
- This **variance** depends on the **codependence** between **individual contributors**:

$$\sigma^2 \approx \sum_i \sigma_i^2 + \sum_i \sum_{j>i} 2\, \gamma_{i,j}\, \sigma_i \sigma_j$$

Variance in regional sea-level rise
Variance from individual contributors
Codependence

- This regional **codependence** has thus far been **neglected or prescribed** (e.g., in IPCC's AR5 and SROCC)

Aims

- Quantify the regional **codependence**
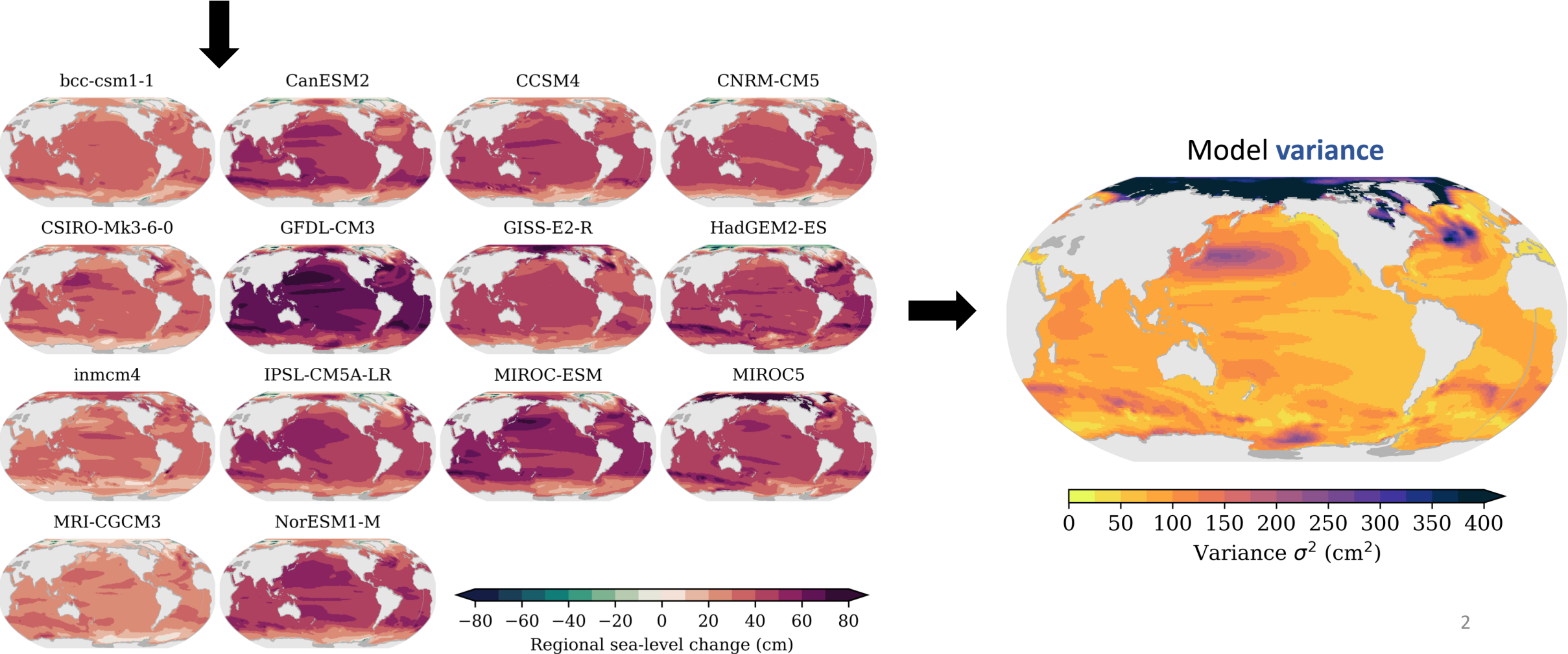- Assess the impact of neglected/prescribed **codependence** on the **variance** in regional sea-level rise

Method: determine sea-level **contributors** from output of 14 CMIP5 models (2081-2100, RCP4.5)

Contributor**	Method	Primary reference
Sterodynamic	CMIP5 output	-
Glaciers	glacier model	Marzeion et al (2012)
Greenland SMB	parameterisation*	Fettweis et al (2013)
Antarctic SMB	parameterisation*	Gregory & Huybrechts (2006)
Antarctic dynamics	parameterisation*	Levermann et al. (2020)

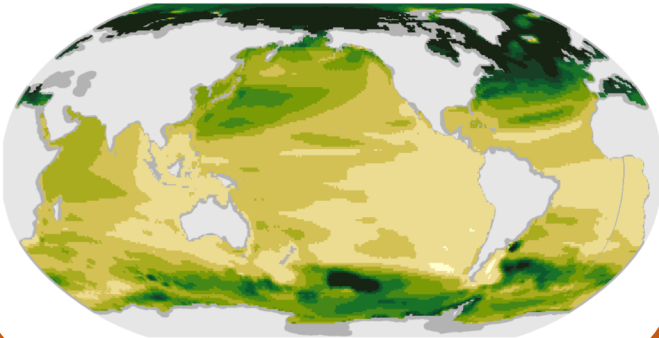* Based on regional CMIP5 output, not global mean surface temperature

** Not included:
- Greenland dynamics (largely ESM-independent)
- Land water storage (assumed ESM-independent)
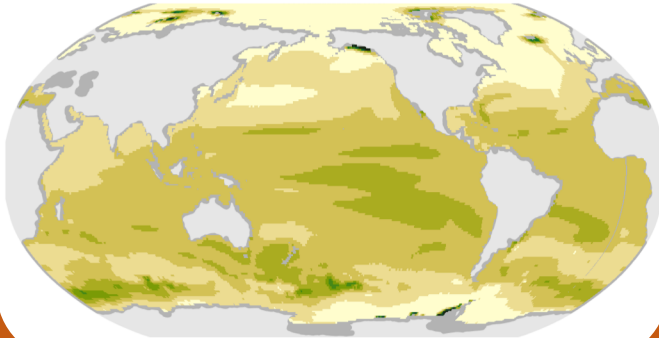- Vertical land motion (ESM-independent)

bcc-csm1-1   CanESM2   CCSM4   CNRM-CM5

CSIRO-Mk3-6-0   GFDL-CM3   GISS-E2-R   HadGEM2-ES

inmcm4   IPSL-CM5A-LR   MIROC-ESM   MIROC5

MRI-CGCM3   NorESM1-M

Regional sea-level change (cm)
−80 −60 −40 −20 0 20 40 60 80

Model **variance**

Variance σ^2 (cm^2)
0 50 100 150 200 250 300 350 400

Results: decomposing model **variance**

$$\sigma^2 \approx \sum_i \sigma_i^2 + \sum_i \sum_{j>i} 2\,\gamma_{i,j}\,\sigma_i\sigma_j$$

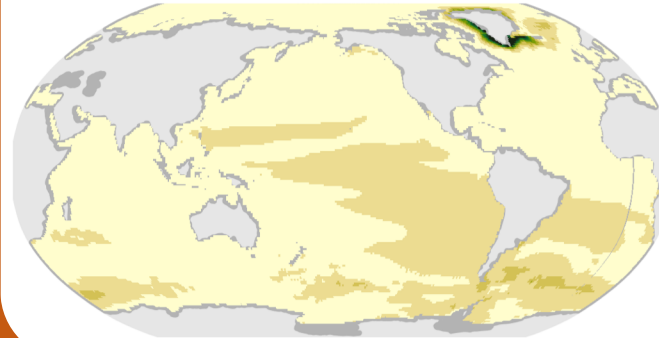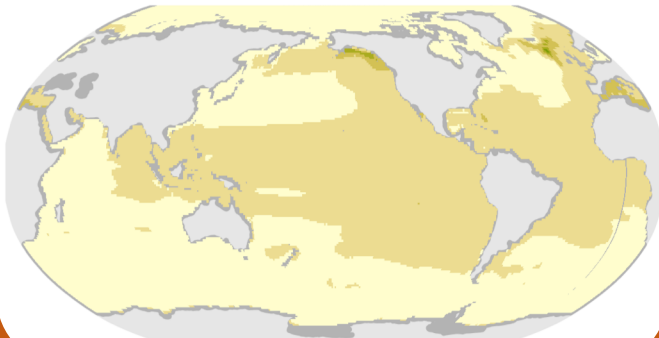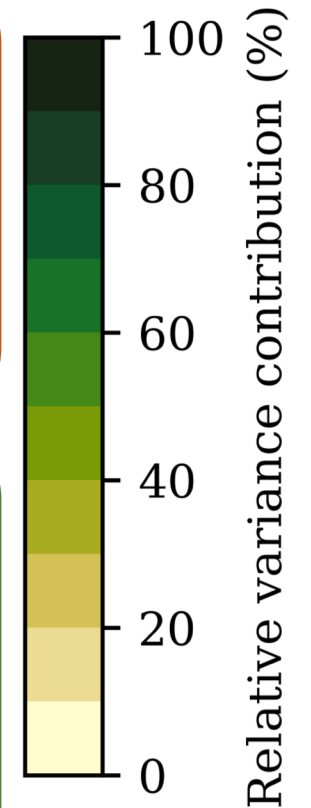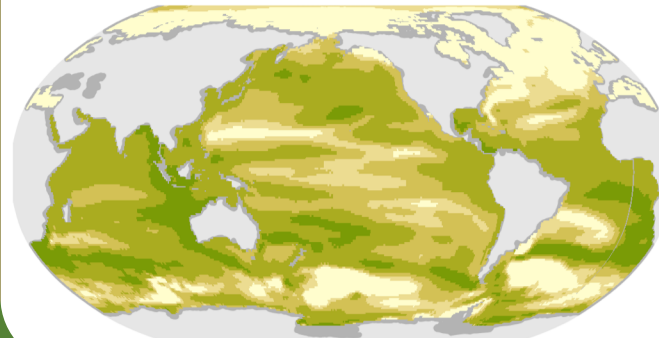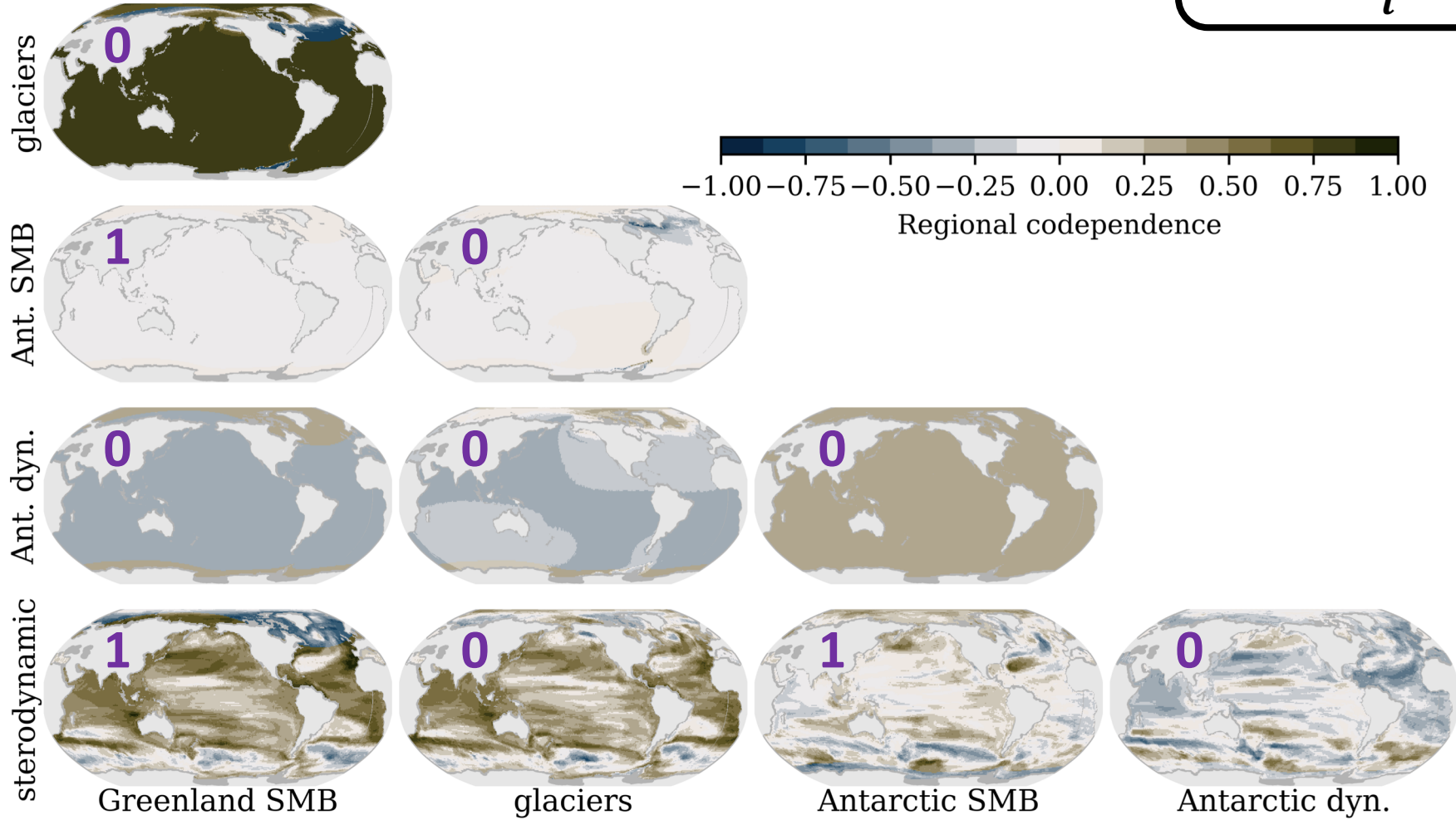**Conclusion: cross-terms** constitute approximately 40% of the model **variance**, indicating the importance of **codependence**
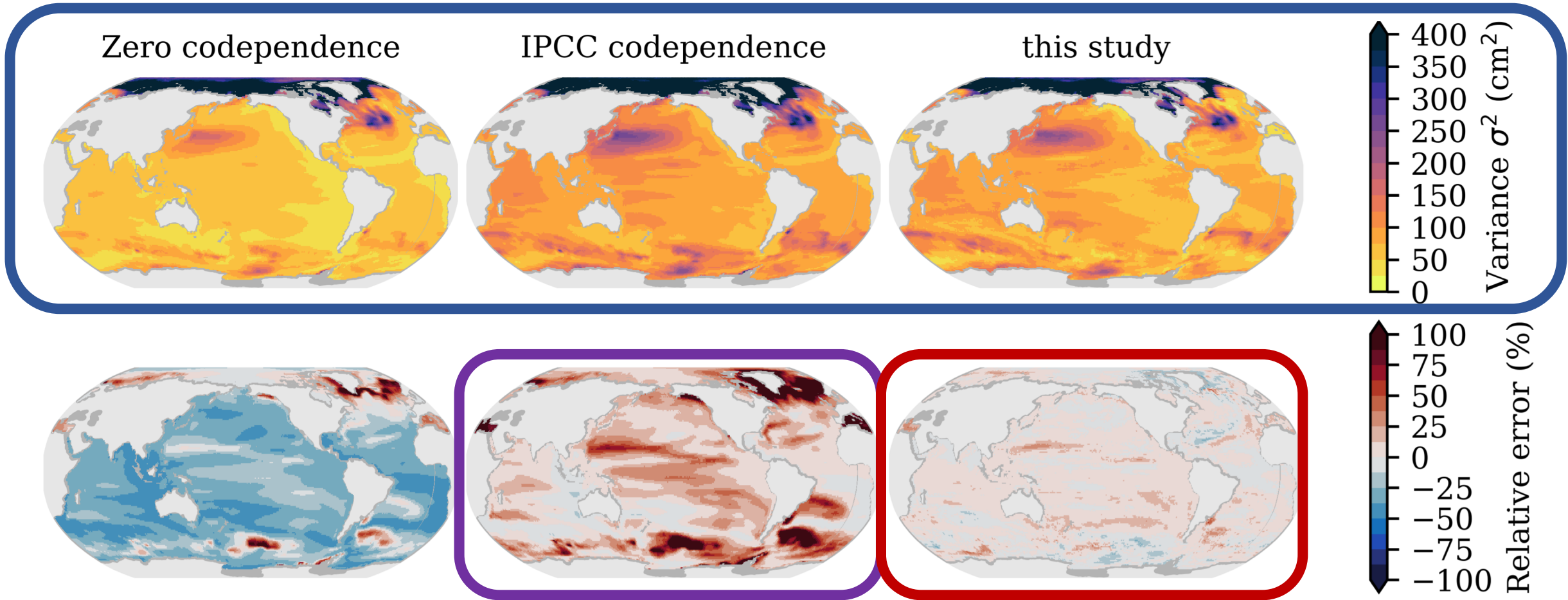
Results: quantifying regional **codependence**

$$\sigma^2 \approx \sum_i \sigma_i^2 + \sum_i \sum_{j>i} 2\ \gamma_{i,j}\ \sigma_i \sigma_j$$

Conclusion: codependence varies regionally and deviates strongly from the **homogeneous values prescribed in AR5 & SROCC**

Results: the impact of prescribed **codependence** on **variance**

Conclusion: prescribed IPCC codependence leads to an overall **<u>overestimation</u>** of the **variance** in regional sea-level rise
ensemble-derived codependence allows for an **<u>accurate approximation</u>** of model **variance**