ODEN INSTITUTE FOR COMPUTATIONAL ENGINEERING & SCIENCES

Leveraging Uncertainty Quantification to Design Ocean Climate Observing Systems

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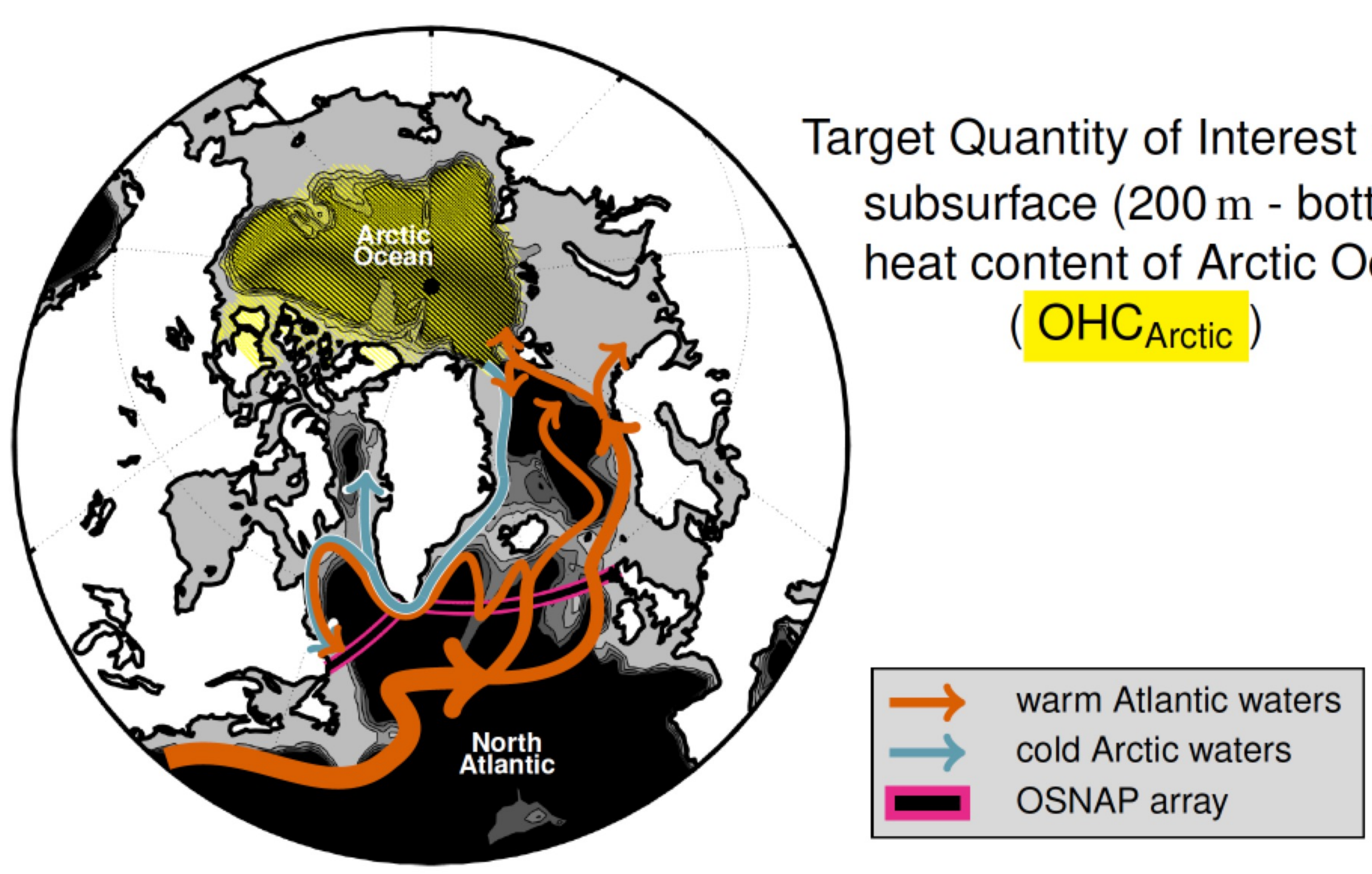
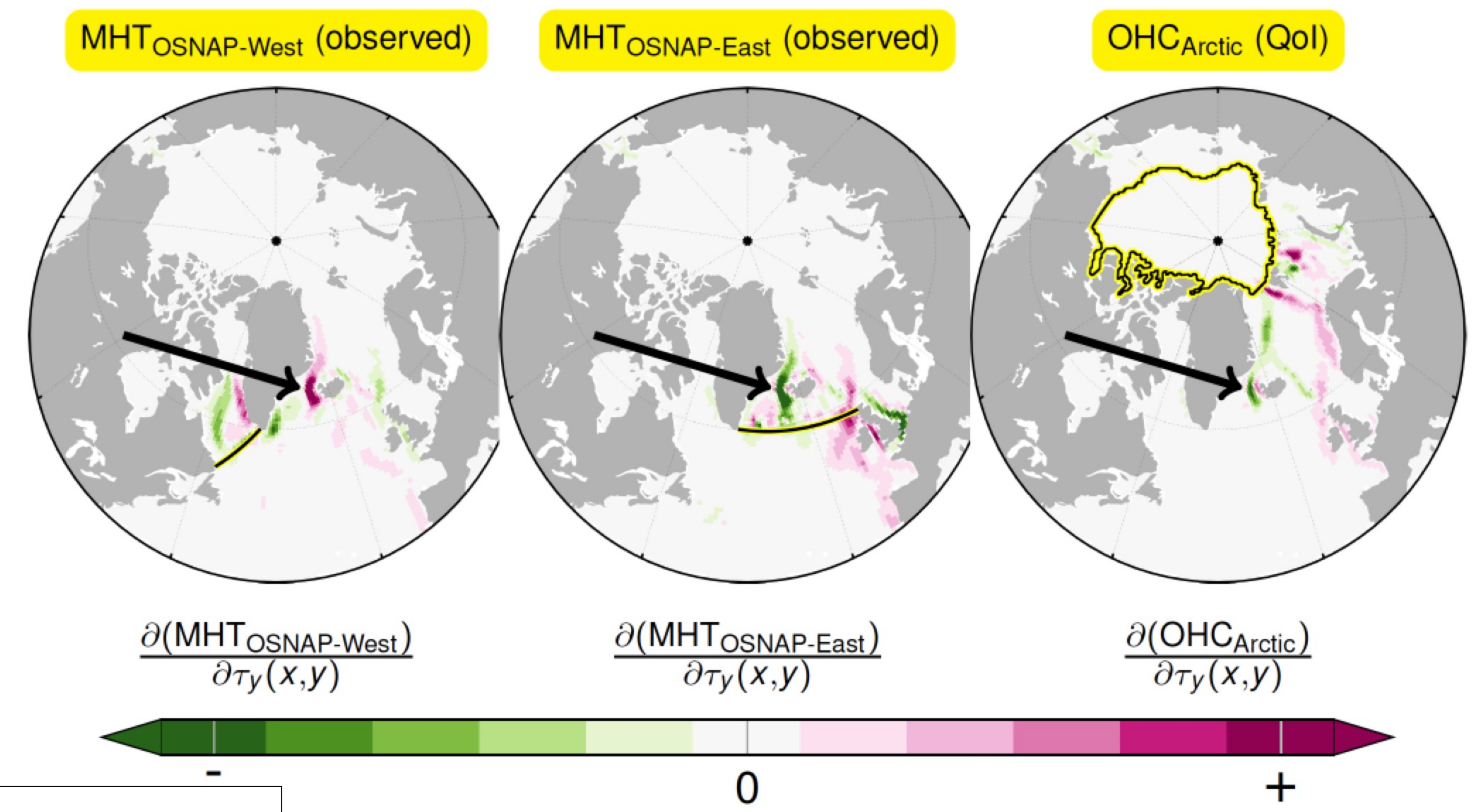
Define mission goals ("Target")



Target Quantity of Interest (QoI): subsurface (200 m - bottom) heat content of Arctic Ocean (OHC_{Arctic})

Exploit ocean connectivity!
Arctic OHC may covary with better observed quantities elsewhere.

Adjoint model identifies all origins of (co)variation



Sensitivity to meridional wind stress τ_y
(accumulated over 5 years)

computed with MITgcm adjoint

- **Loose, N. and P. Heimbach, 2021:** Leveraging Uncertainty Quantification to Design Ocean Climate Observing Systems. *J. Adv. Model. Earth Syst.*, 13(4), doi:10.1029/2020MS002386
- **Loose, N., P. Heimbach, H. Pillar, and K. Nisancioglu, 2020:** Quantifying Dynamical Proxy Potential through Shared Adjustment Physics in the North Atlantic. *J. Geophys. Res.*, 125(9), doi:10.1029/2020JC016112

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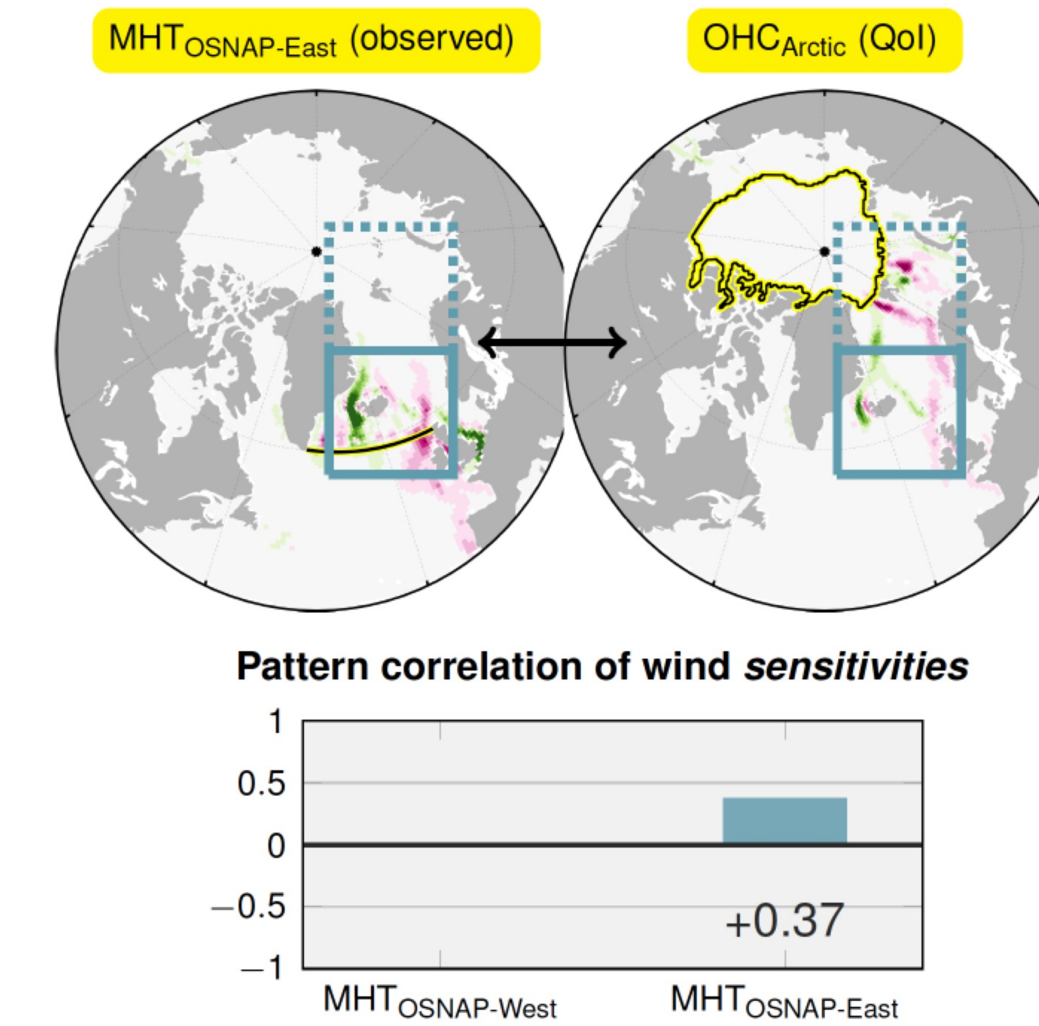
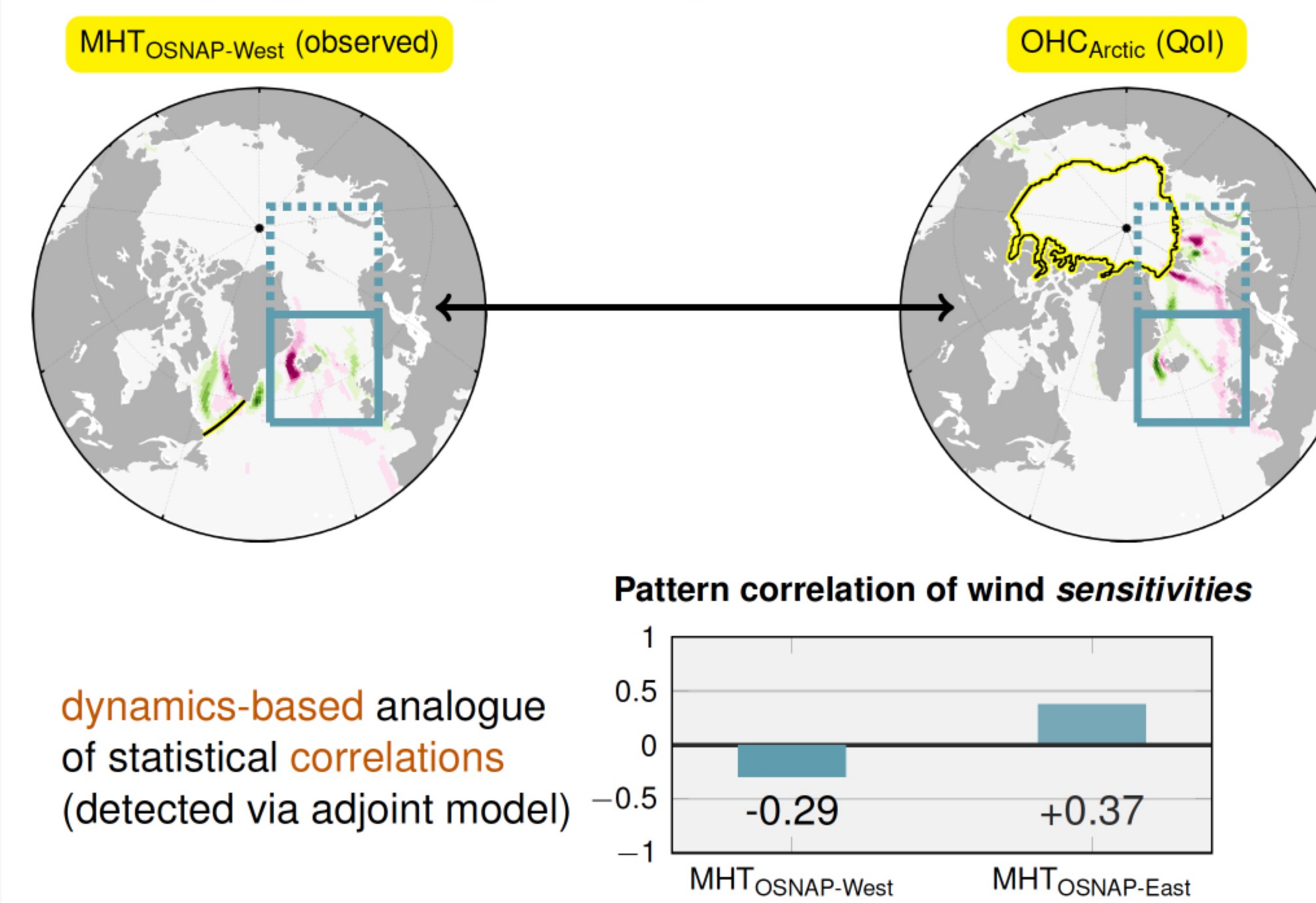
Quantifying the degree of dynamics-based covariation

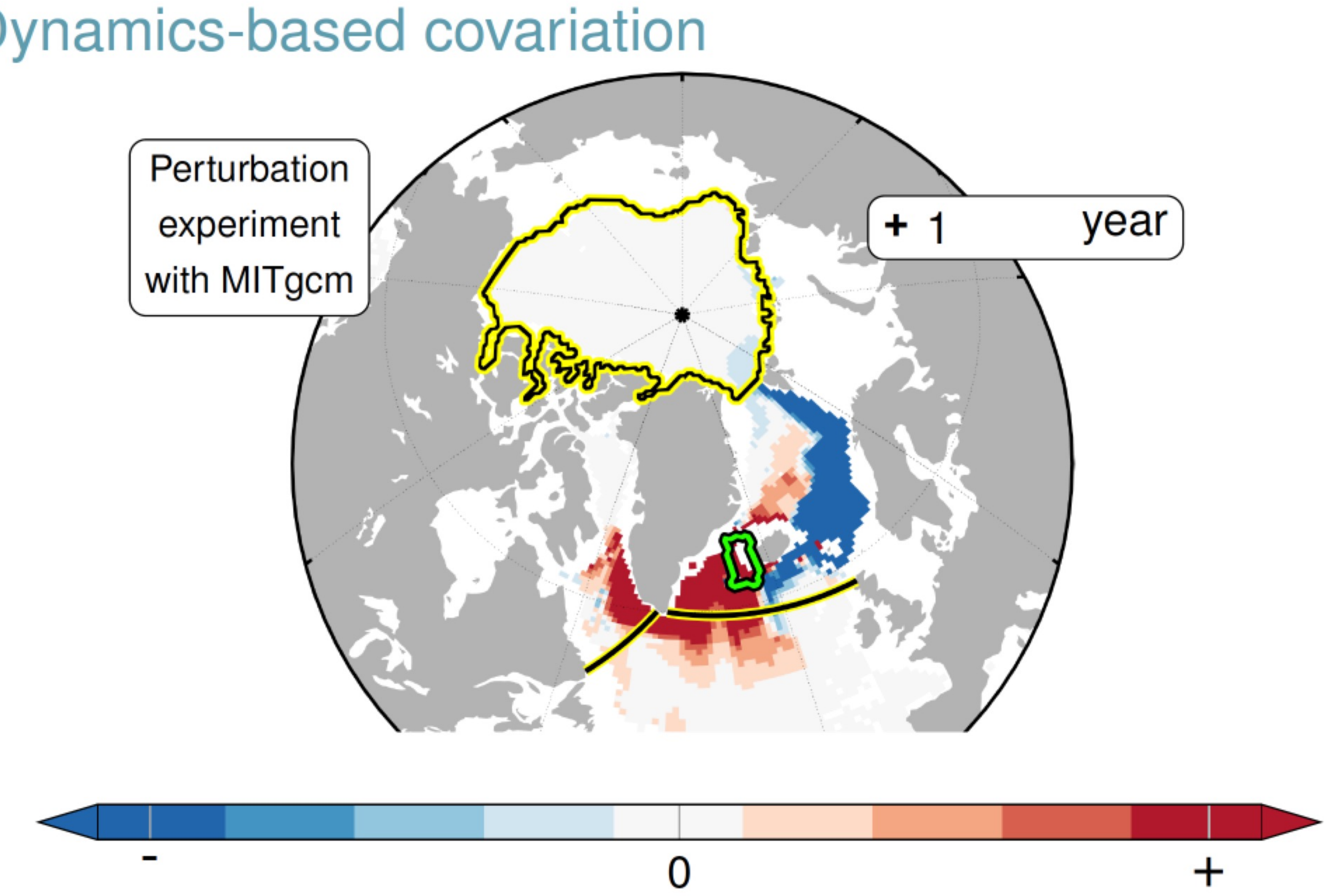


Quantifying the degree of dynamics-based covariation



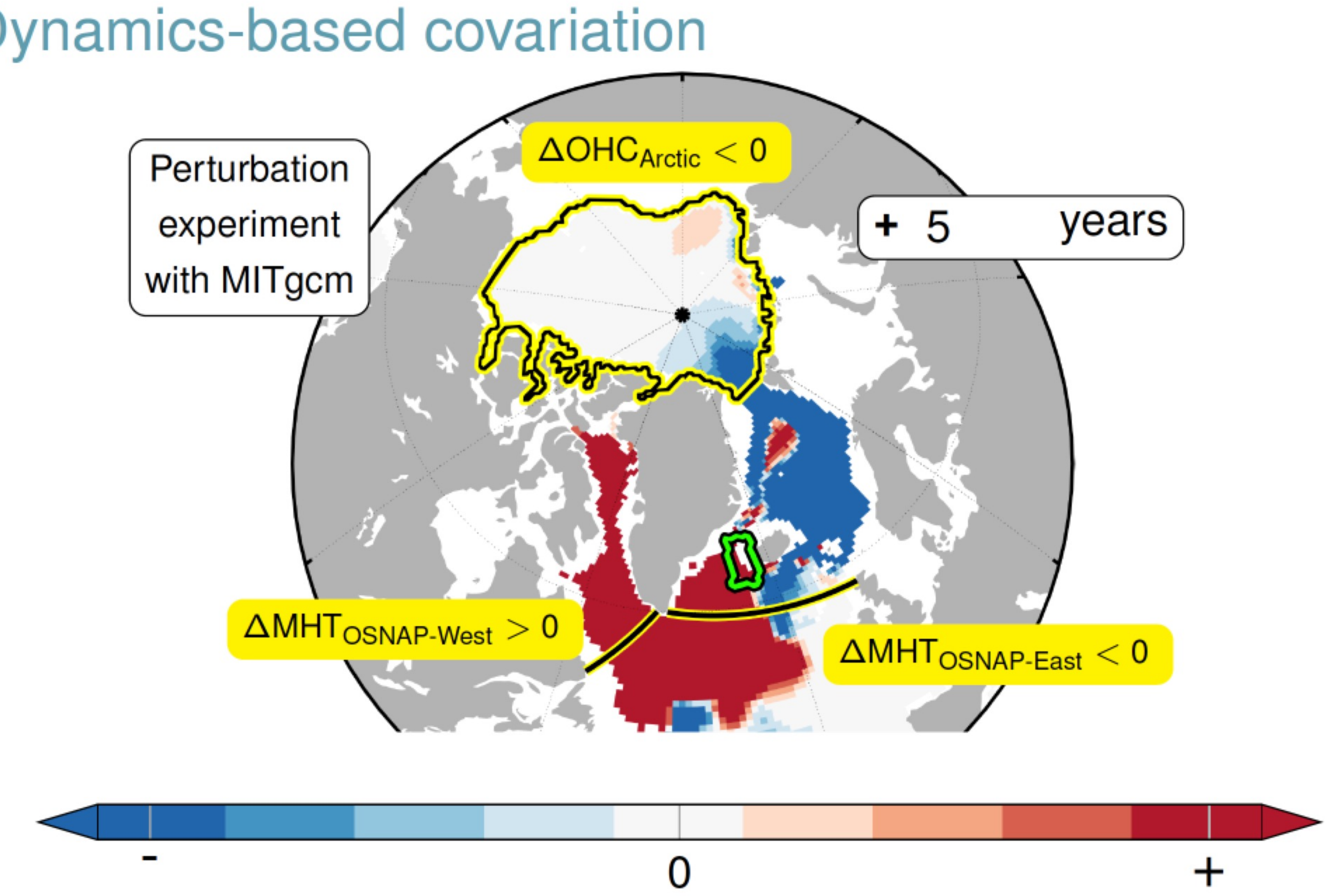
dynamics-based analogue of statistical correlations (detected via adjoint model)

Dynamics-based covariation



Temperature response [°C] at 475 m
Positive northward **wind anomaly** ($\Delta\tau_y > 0$) in ☐ (west of Iceland)

Dynamics-based covariation

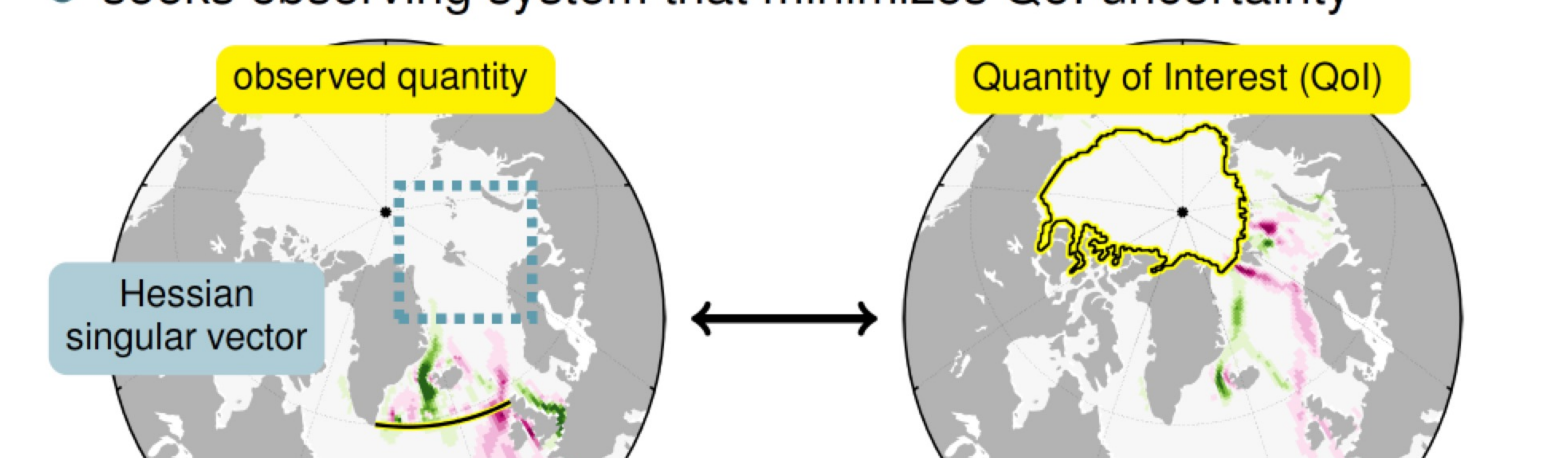


Temperature response [°C] at 475 m
Positive northward **wind anomaly** ($\Delta\tau_y > 0$) in ☐ (west of Iceland)

The underlying mathematical framework

Targeted observations via Hessian Uncertainty Quantification

- seeks observing system that minimizes QoI uncertainty



Strong *sensitivity* pattern correlation
=
effective reduction in QoI uncertainty (via dynamics-based covariation)

- formalizes *this concept*
- systematically extracts independent sensitivity information from distinct observations (incl. data uncertainty)
- does not require actual measurement values