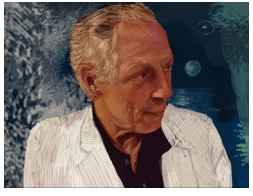
The rate of information transfer as a measure of ocean-atmosphere interactions

David Docquier

Royal Meteorological Institute of Belgium

Contributors: S. Vannitsem, A. Bellucci, C. Frankignoul

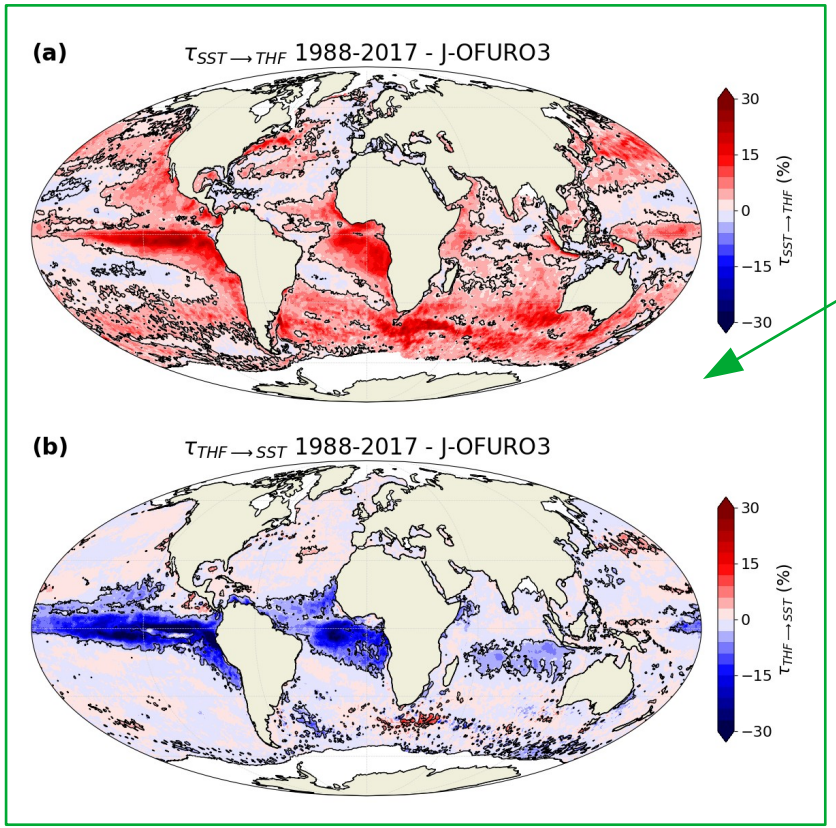


EGU General Assembly 2023

Vienna, 24 April 2023

Key results

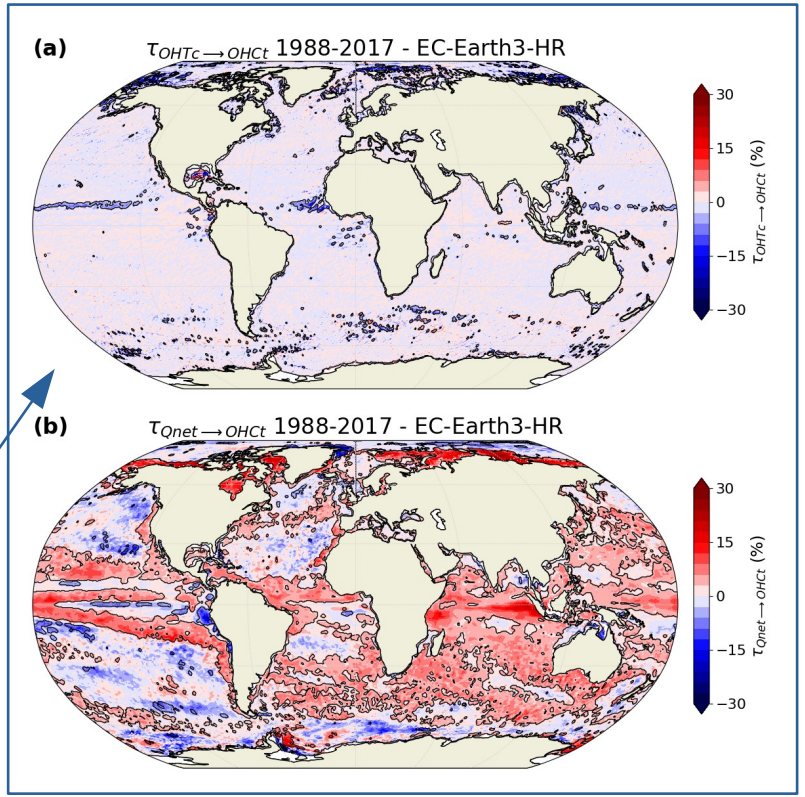
1st case study:
SST - Turbulent heat flux
Satellite data



1. Stronger ocean influence (vs. atmosphere) in many regions of the world based on satellite data

2. Lower number of regions with a significant ocean dynamical influence in high-resolution models vs. low-resolution models

2nd case study:
Ocean heat budget upper 50m
Climate models



Docquier et al. (accepted), The rate of information transfer as a measure of ocean-atmosphere interactions, *Earth System Dynamics*

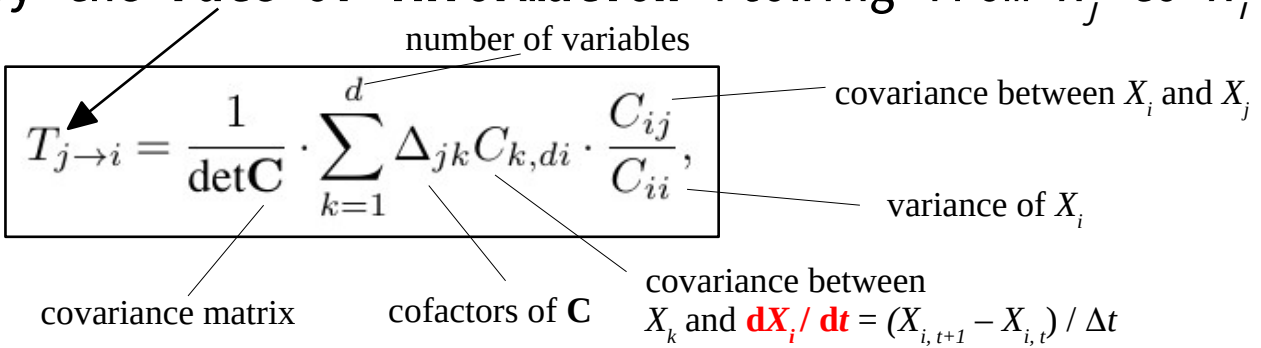
Docquier et al. (in review), Interactions between ocean heat budget terms in HighResMIP climate models measured by the rate of information transfer, *EGUsphere*

Liang-Kleeman rate of information transfer

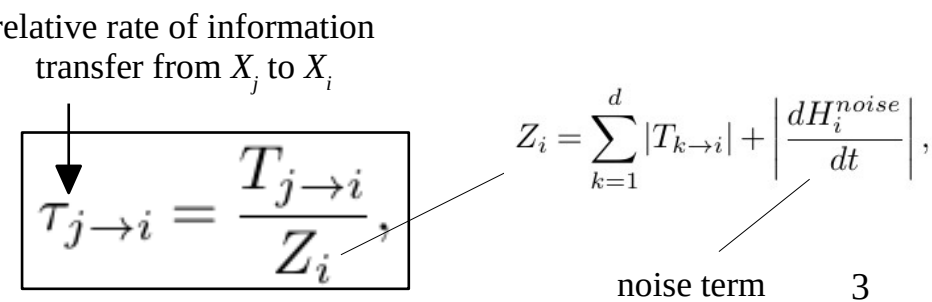
- Correlation (even if lagged) does not necessarily imply causation!

- Causality measured by the **rate of information** flowing from X_j to X_i :

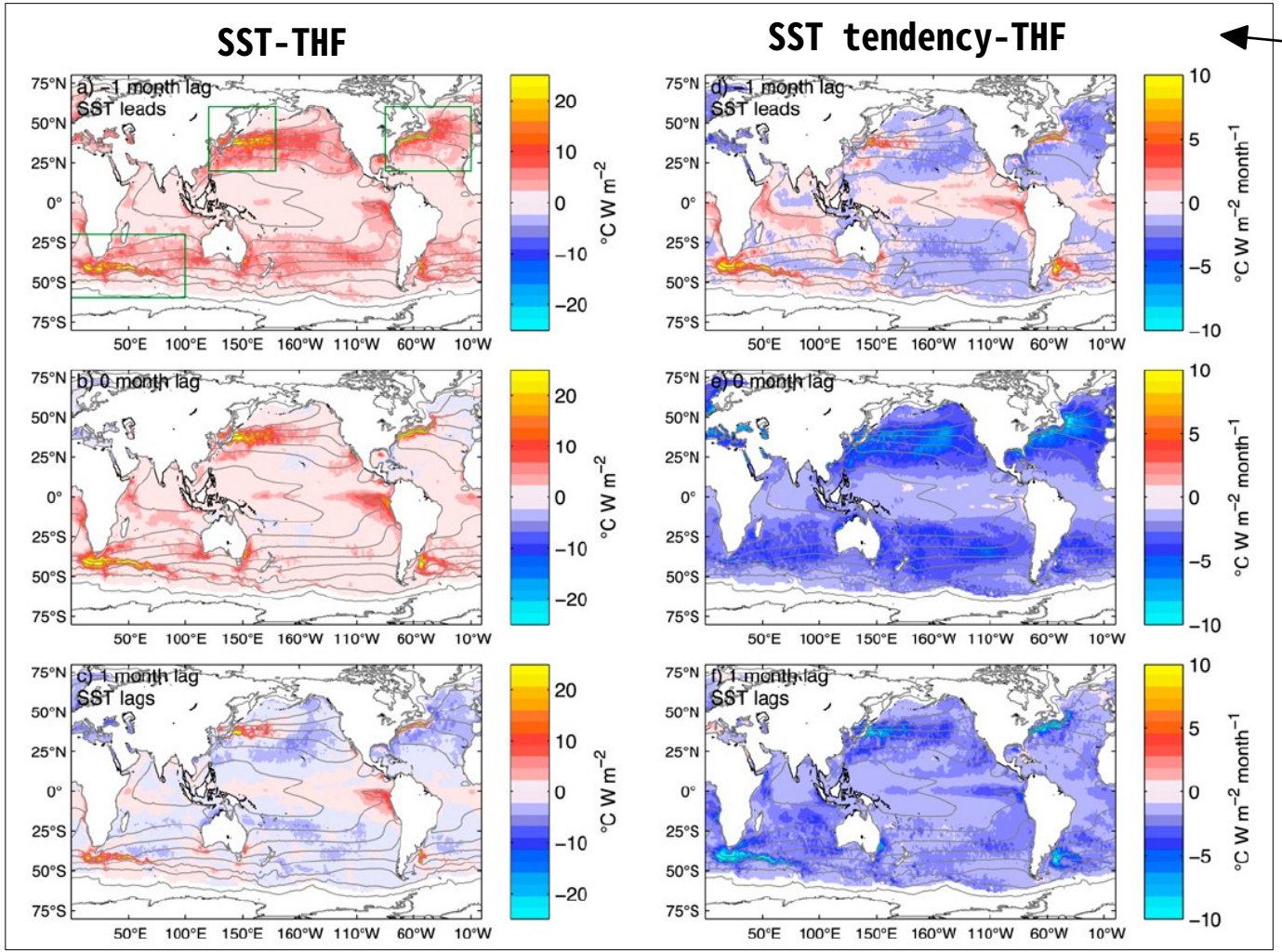
  (Liang, 2021)



- **Normalization:**
  - If $|\tau_{j\to i}|$ = 0%: X_j does not influence X_i
  - If $|\tau_{j\to i}|$ > 0%: X_j influences X_i
  - If $\tau_{j\to i}$ > 0%: X_j causes X_i to be more uncertain
  - If $\tau_{j\to i}$ < 0%: X_j causes X_i to be more certain



1st case study: SST – Turbulent heat flux (THF)

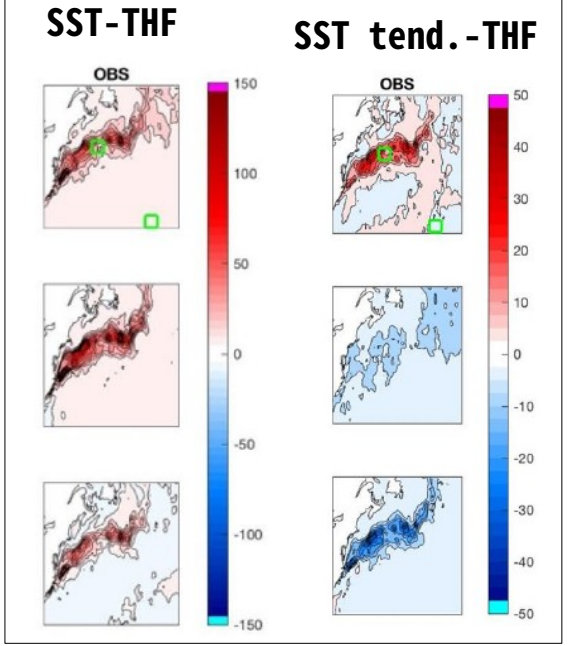


Bishop et al. (2017)

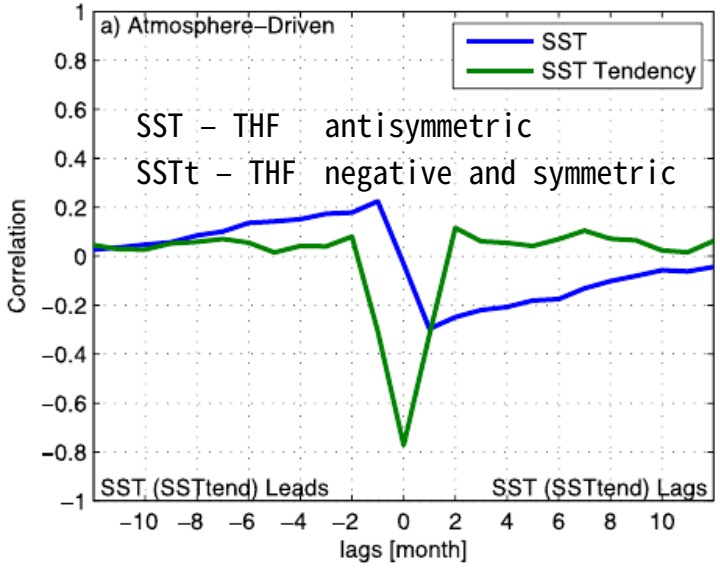
OI SST (0.25°) & OAFlux (1°)

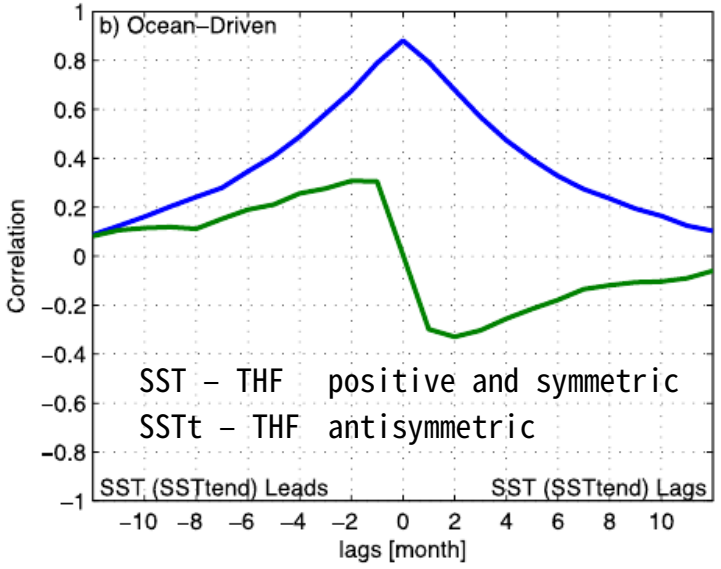
Bellucci et al. (2021)

J-OFURO3 (0.25°) & HighResMIP



1st case study: Background & Methods





Bishop et al. (2017); based on energy balance model from Wu et al. (2006)

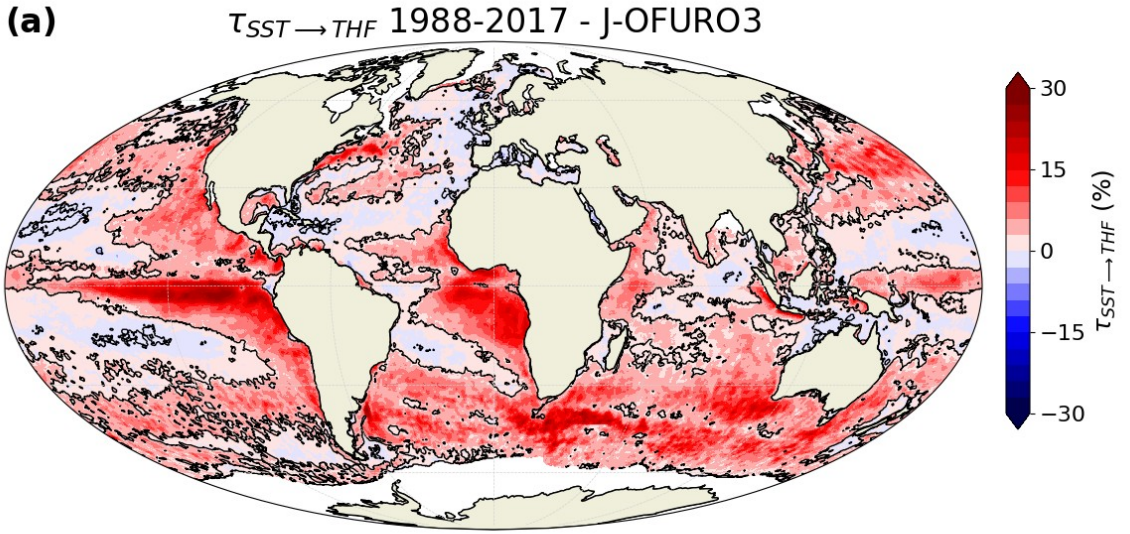
- 3 variables: SST, SST tendency, turbulent heat flux (THF = latent + sensible)
- J-OFURO3 satellite observations (0.25° resolution)
- Monthly data over 1988-2017
- Confirmed with SeaFlux satellite observations

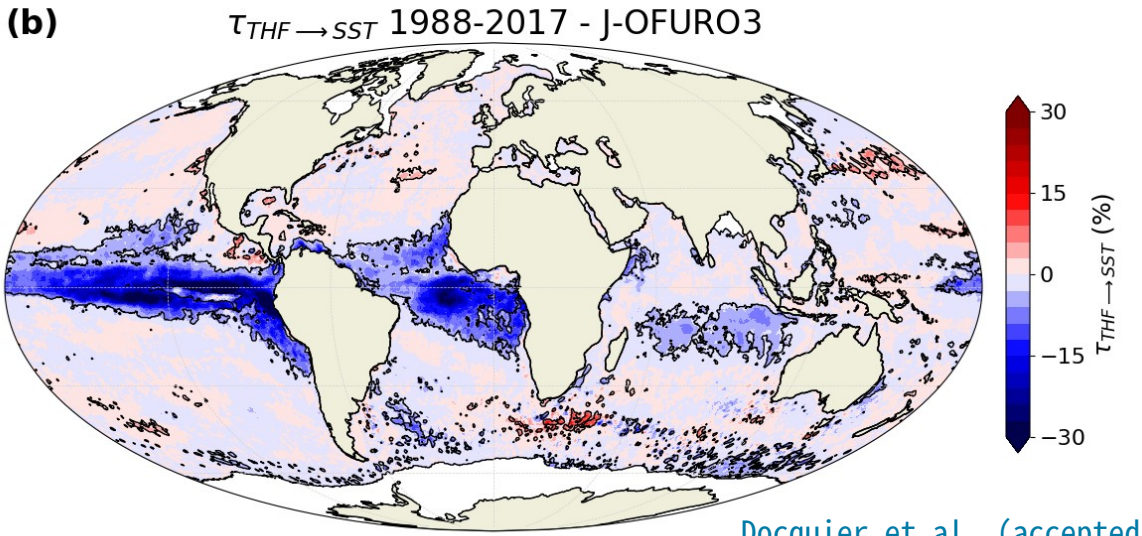
Docquier et al. (accepted)

SST – THF
(taking SST tendency into account)

- **SST → THF:**
  - Significant in a large number of regions
  - > 0: SST variability increases THF variability

- **THF → SST:**
  - Lower number of regions, including equatorial regions
  - < 0: THF variability decreases SST variability



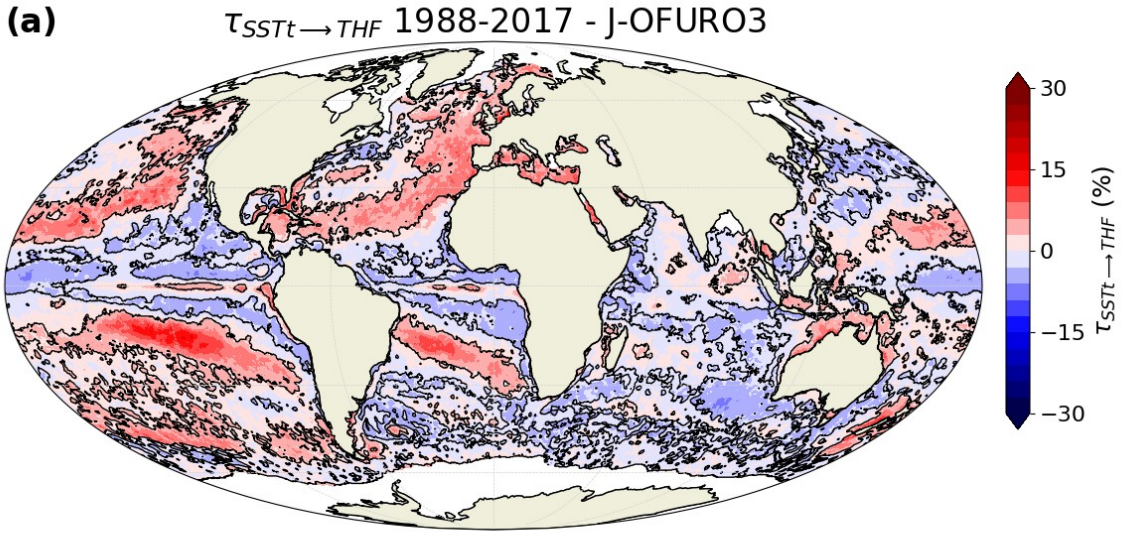


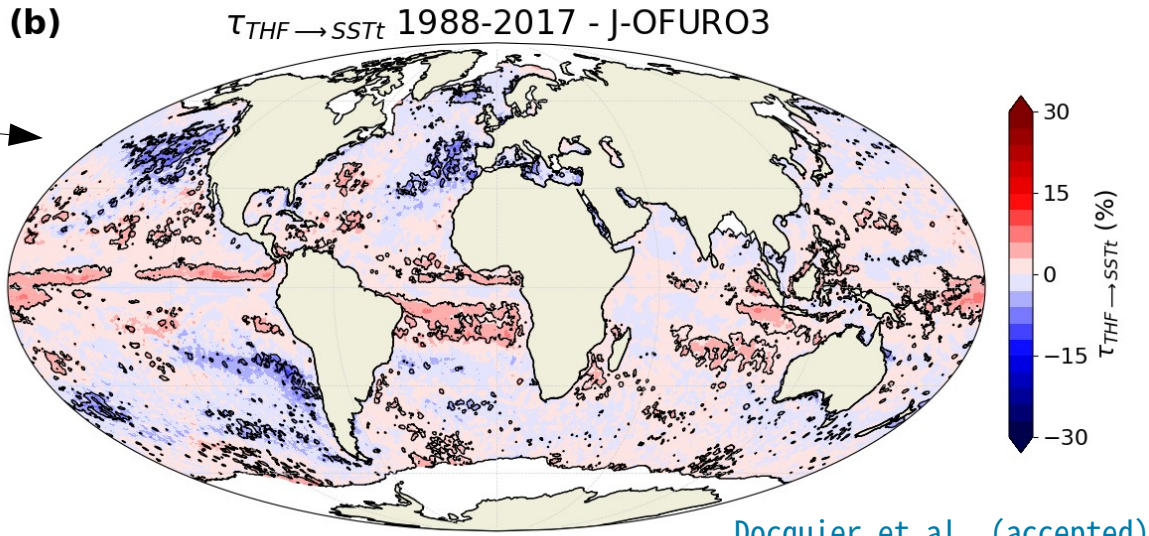
Docquier et al. (accepted)

SST tendency – THF
(taking SST into account)

- **SSTt → THF:**
  - Significant in a large number of regions
  - > 0 and < 0

- **THF → SSTt:**
  - Lower number of regions, including North Atlantic, northeastern Pacific, and tropical regions
  - > 0 and < 0





Docquier et al. (accepted)

2nd case study: Ocean heat budget upper 50m

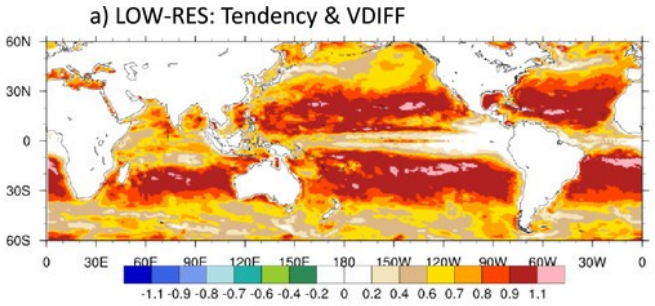
Thermodynamical contribution

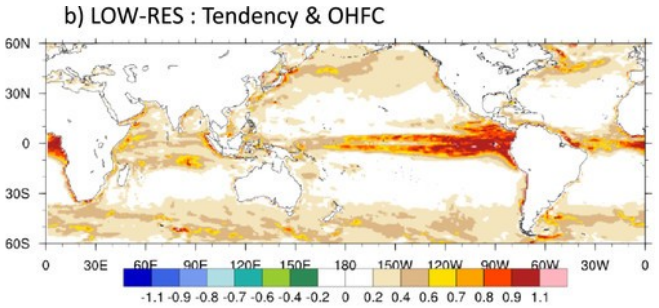
VDIFF: vertical diffusion including surface heat flux

Dynamical contribution

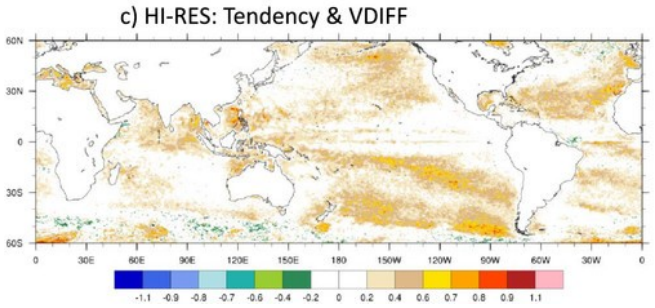
OHFC: ocean heat flux convergence

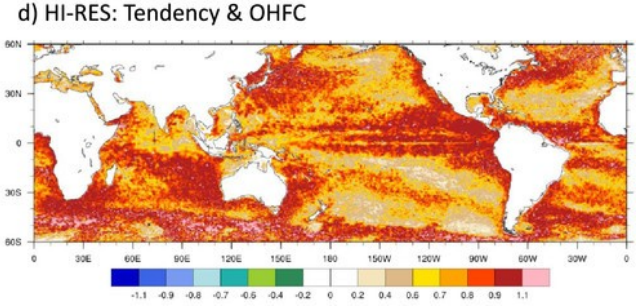
Low resolution





High resolution





Small et al. (2020)

- 3 variables: ocean heat content (OHC) tendency, ocean heat transport (OHT) convergence, net surface heat flux (Qnet)
- HighResMIP climate models (1° vs. 0.25° in the ocean)
- Monthly data over 1988-2017

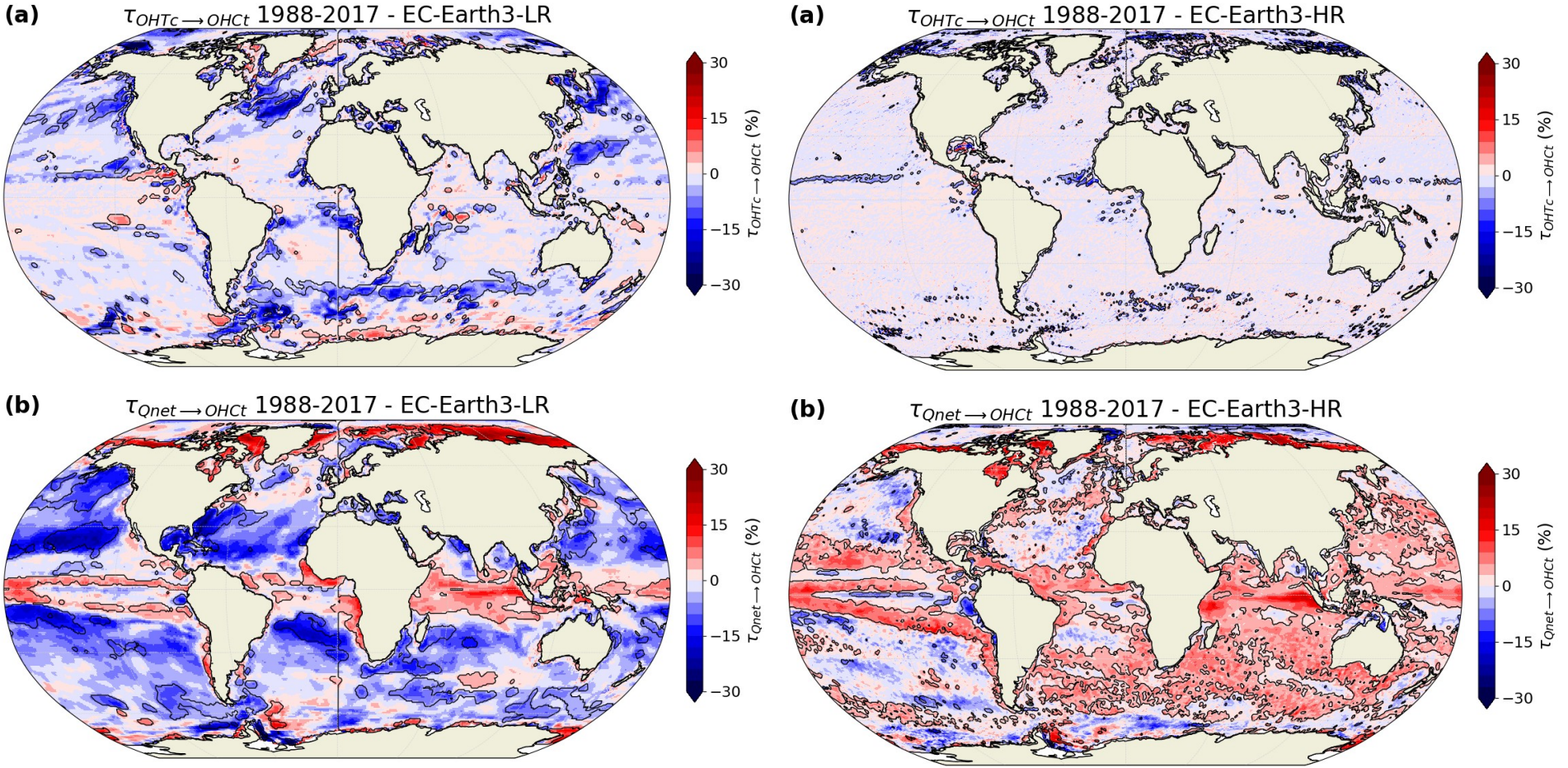
Docquier et al. (in review)

Low resolution

High resolution

Dynamical influence

Thermodynamical influence

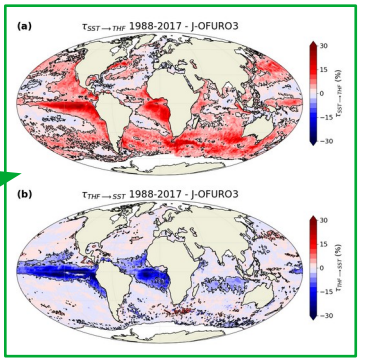


Docquier et al. (in review)

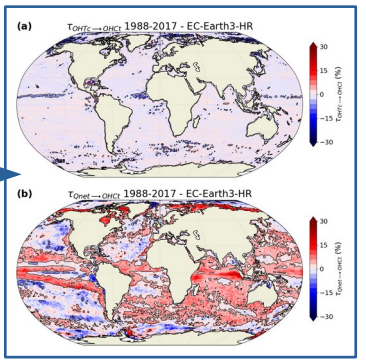
Conclusions

- The **Liang-Kleeman rate of information transfer** allows to quantify the directional dependence between variables and goes beyond correlation analyses

- **1st case study: Larger number of regions with a significant ocean → atmosphere influence vs. atmosphere → ocean influence based on satellite data**
  Docquier et al. (accepted), The rate of information transfer as a measure of ocean-atmosphere interactions, Earth System Dynamics



- **2nd case study: Lower number of regions with a significant ocean dynamical influence at high resolution vs. low resolution based on global climate models**
  Docquier et al. (in review), Interactions between ocean heat budget terms in HighResMIP climate models measured by the rate of information transfer, EGUsphere



- Comparison to other causal methods is ongoing