Connections between (sub)mesoscale upper ocean physics and climate

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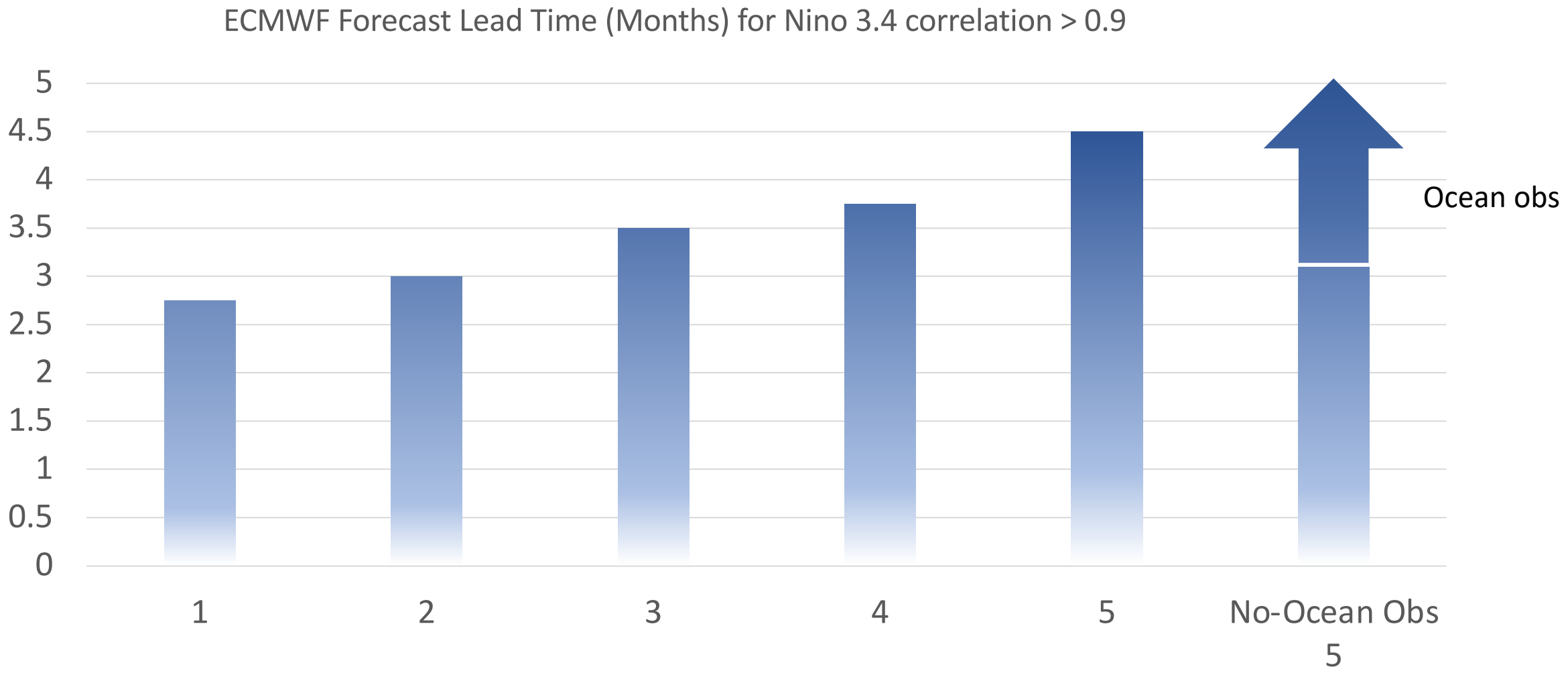
US CLIVAR Summit

Understanding and predicting climate depends on understanding, observing, and predicting the ocean *down to small scales*



Stockdale et al. (2018). *SEAS5 and the Future Evolution of the Long-Range Forecasting System.* Reading: ECMWF Technical Memorandum.

RESEARCH May 2023

CLIMATE ECONOMICS

Persistent effect of El Niño on global economic growth

Christopher W. Callahan[1,2]* and Justin S. Mankin[1,2,3,4]

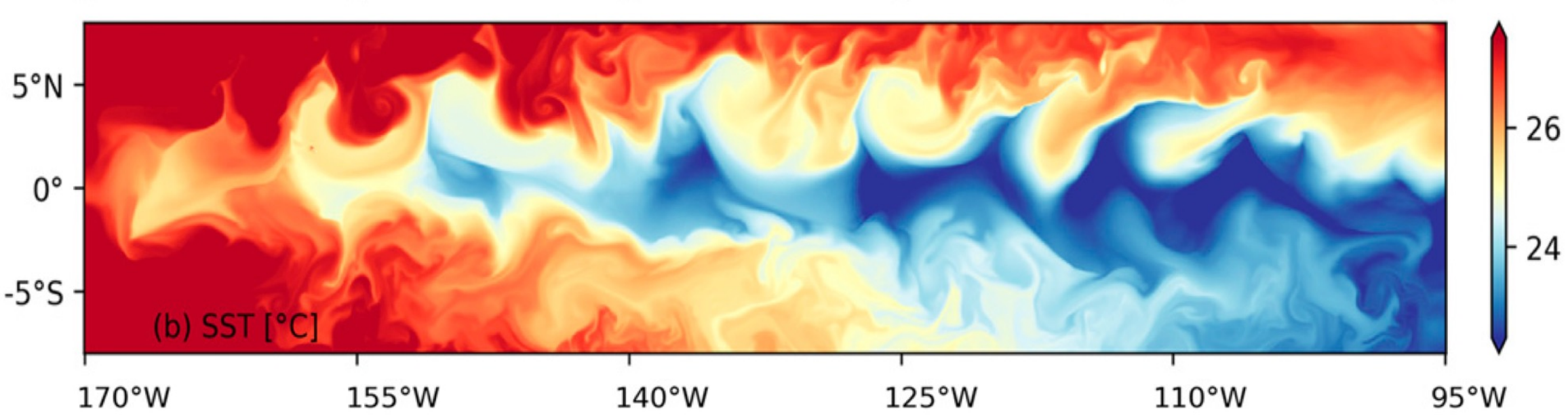
El Niño persistently reduces country-level economic growth; 1982–83 and 1997–98 events cause $4.1 trillion and $5.7 trillion in global income losses

ENSO amplitude and teleconnections from warming are projected to cause $84 trillion in 21st-century economic losses

Can science help understand and mitigate these effects?
Improving predictions is hard but feasible.

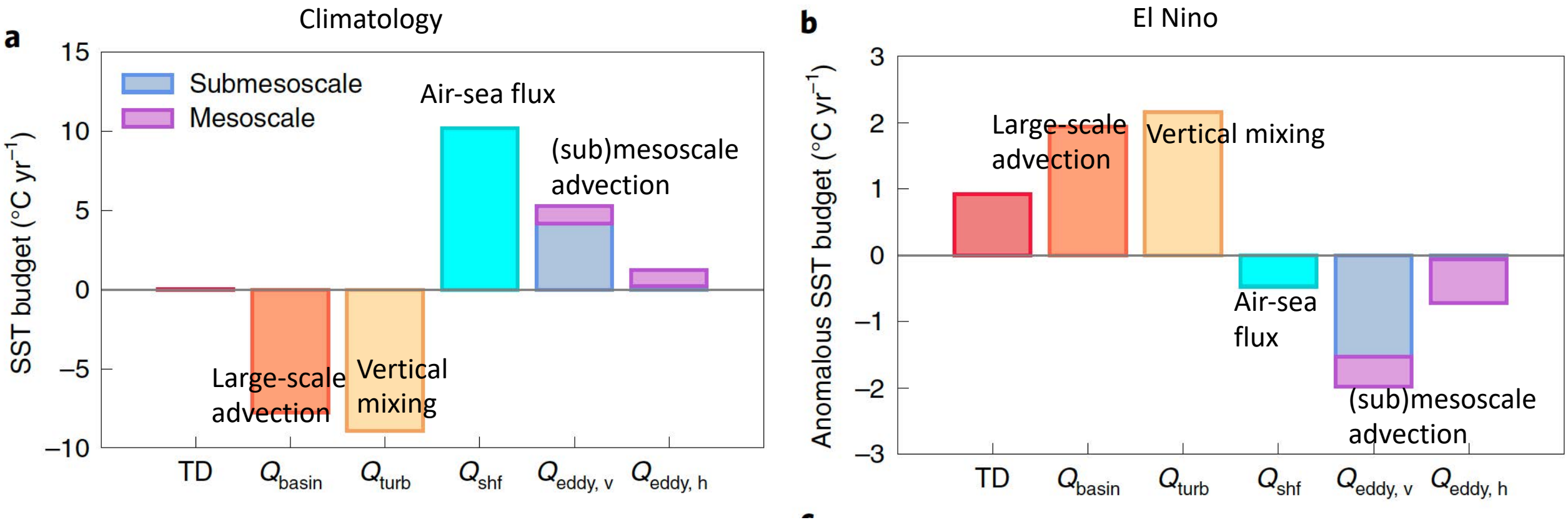
Conceptual / dynamical models minimize the uncertain role of vigorous small-scale variability

Sea-surface temperature



Cherian, Whitt, et al. 2021

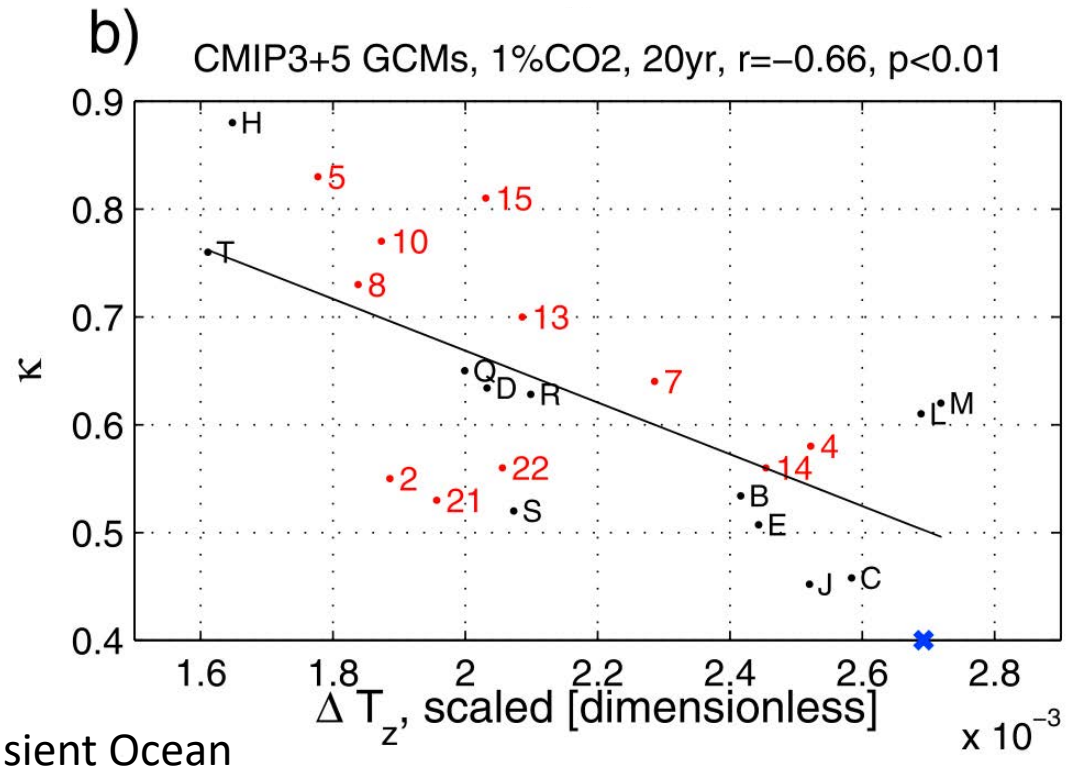
High-resolution models show small-scale ocean physics is significant

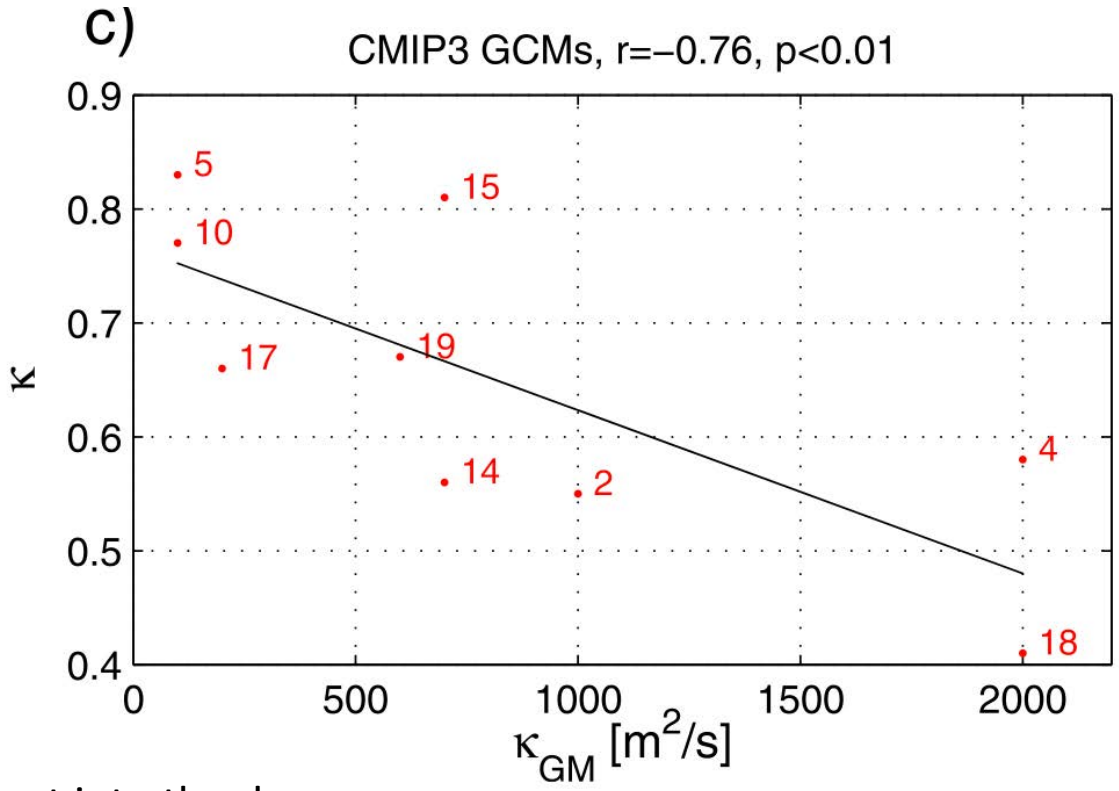


Wang *et al. (2022)*

Transient global warming is mediated by ocean heat uptake; implications for predicting centennial climate and sea level rise

Global Argo and hydrographic observations provide long term monitoring of ocean heat uptake





Transient Ocean heat uptake

Climate feedback

$$N = F - \alpha \Delta T$$

Climate forcing

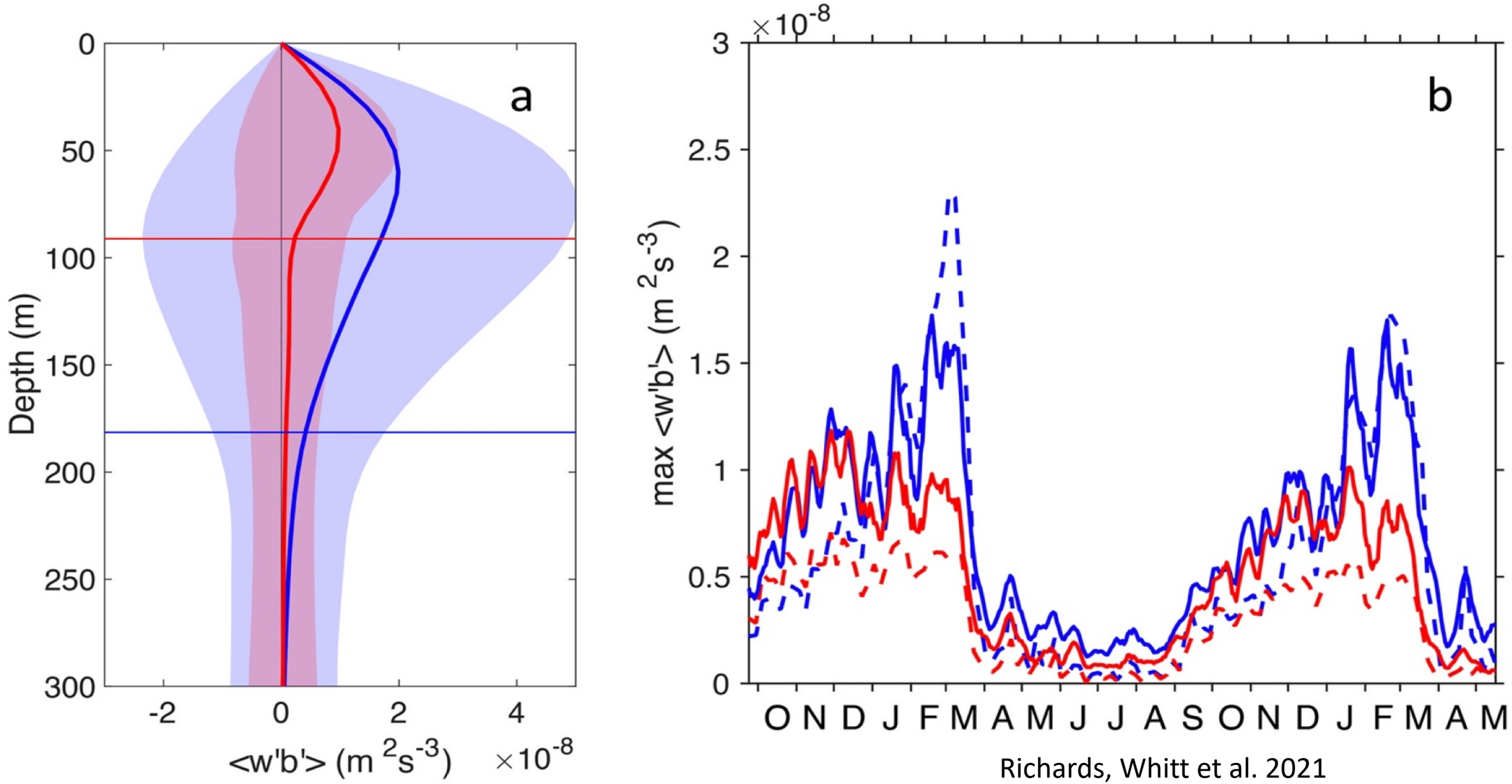
Penetration of heat into the deep ocean modeled based on an efficiency factor

$$N \approx \kappa \Delta T$$

$$\Delta T \approx F/(\alpha + \kappa)$$

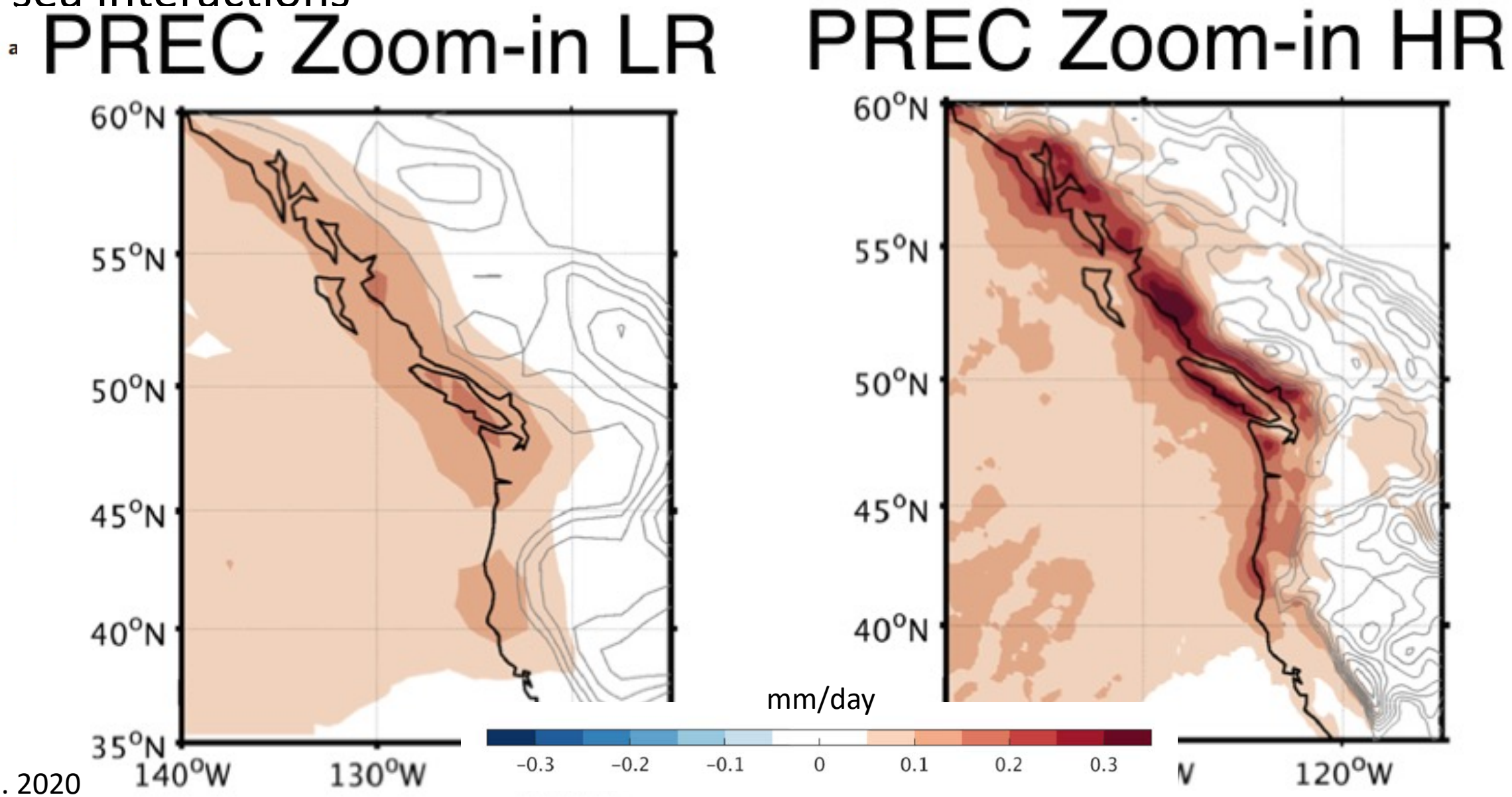
Gregory and Forester (2008)
Kuhlbrodt and Gregory (2012)

Ocean heat budget and response to warming depends on small scales



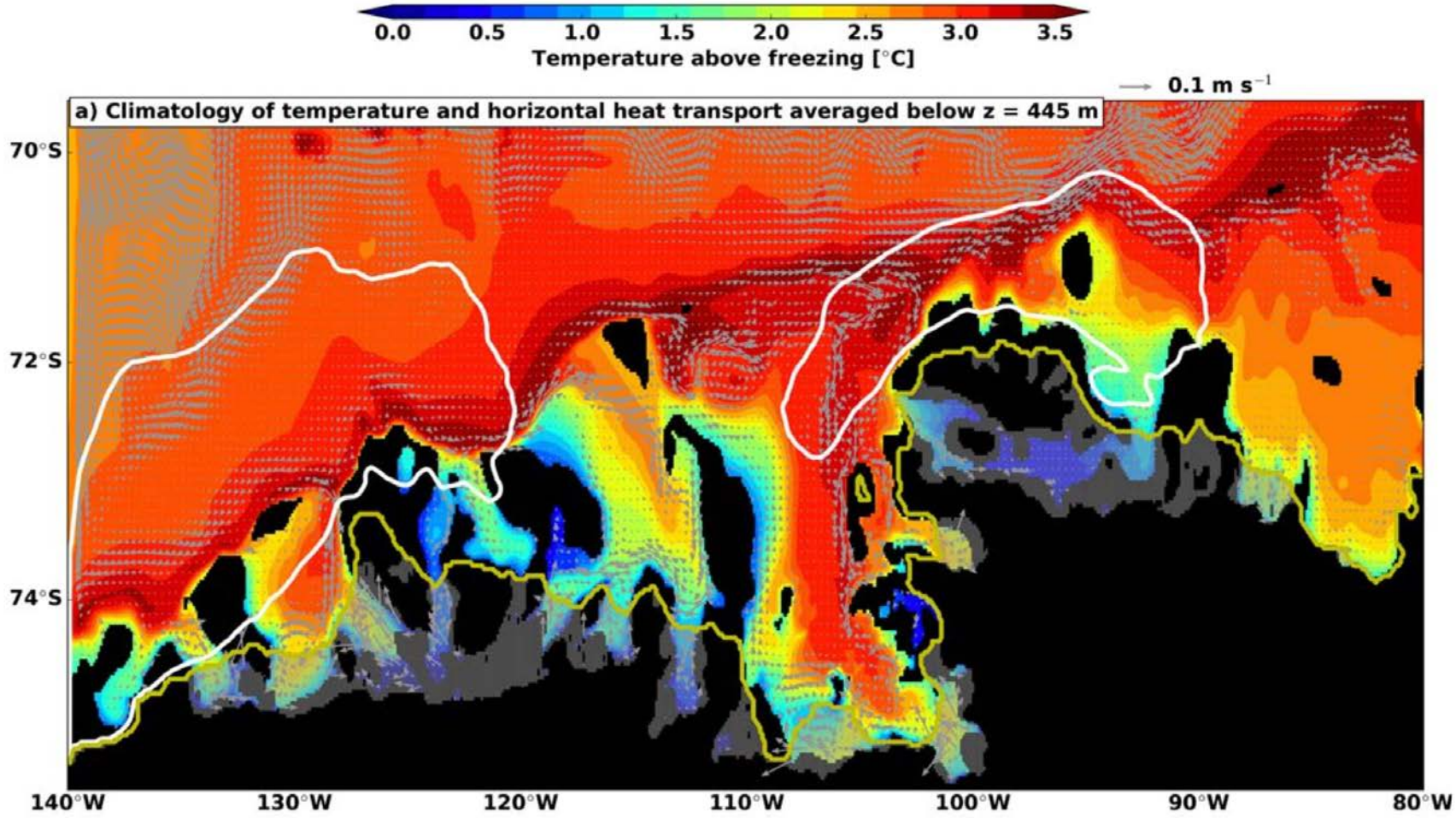
Richards, Whitt et al. 2021

Small-scale processes alter surface fluxes, the atmosphere, and air-sea interactions



Chang et al. 2020

Mesoscale and submesoscale processes alter the pathway of the circulation, incl boundary currents, overflows and mixing, etc. with major impacts on lateral heat transport and heat exchange with sea and land ice as well as the atmosphere



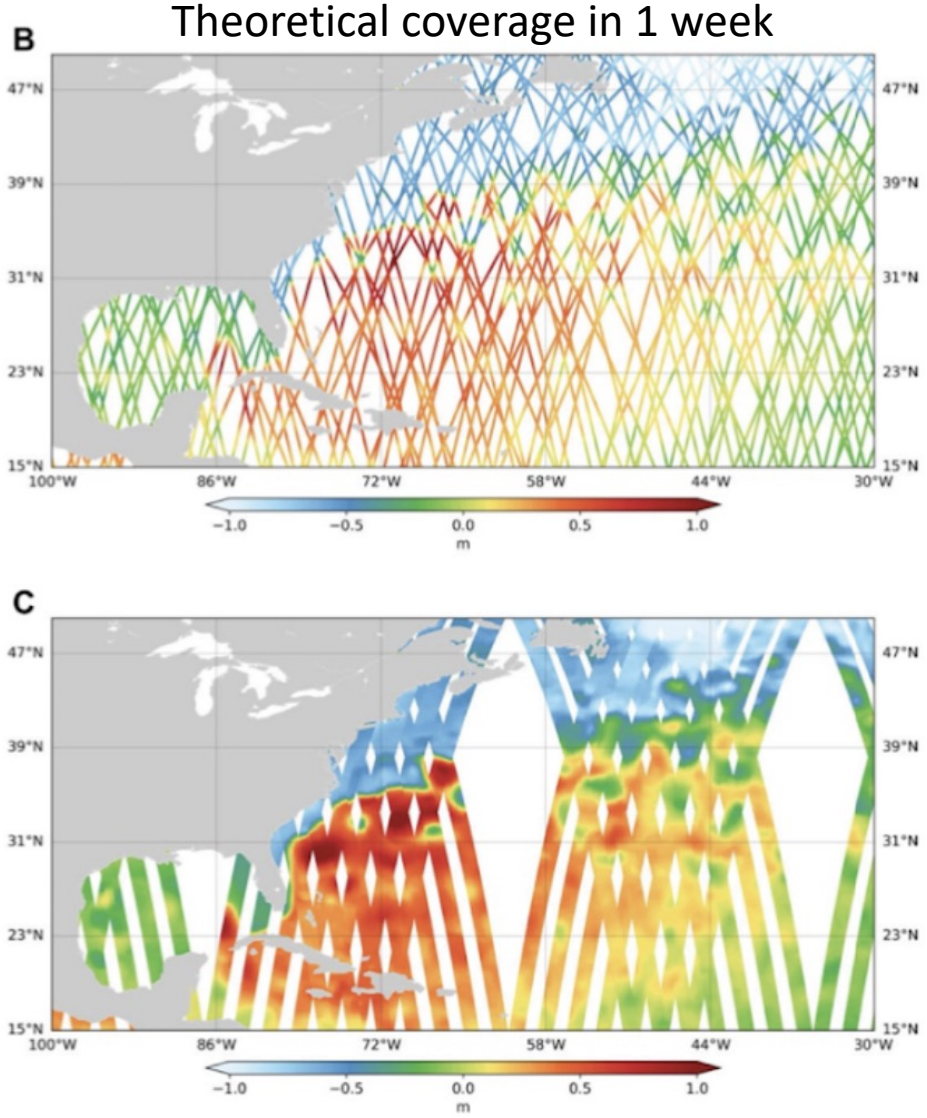
Amundsen Sea Embayment, Antarctica

Kimura et al. incl. Whitt (2017)

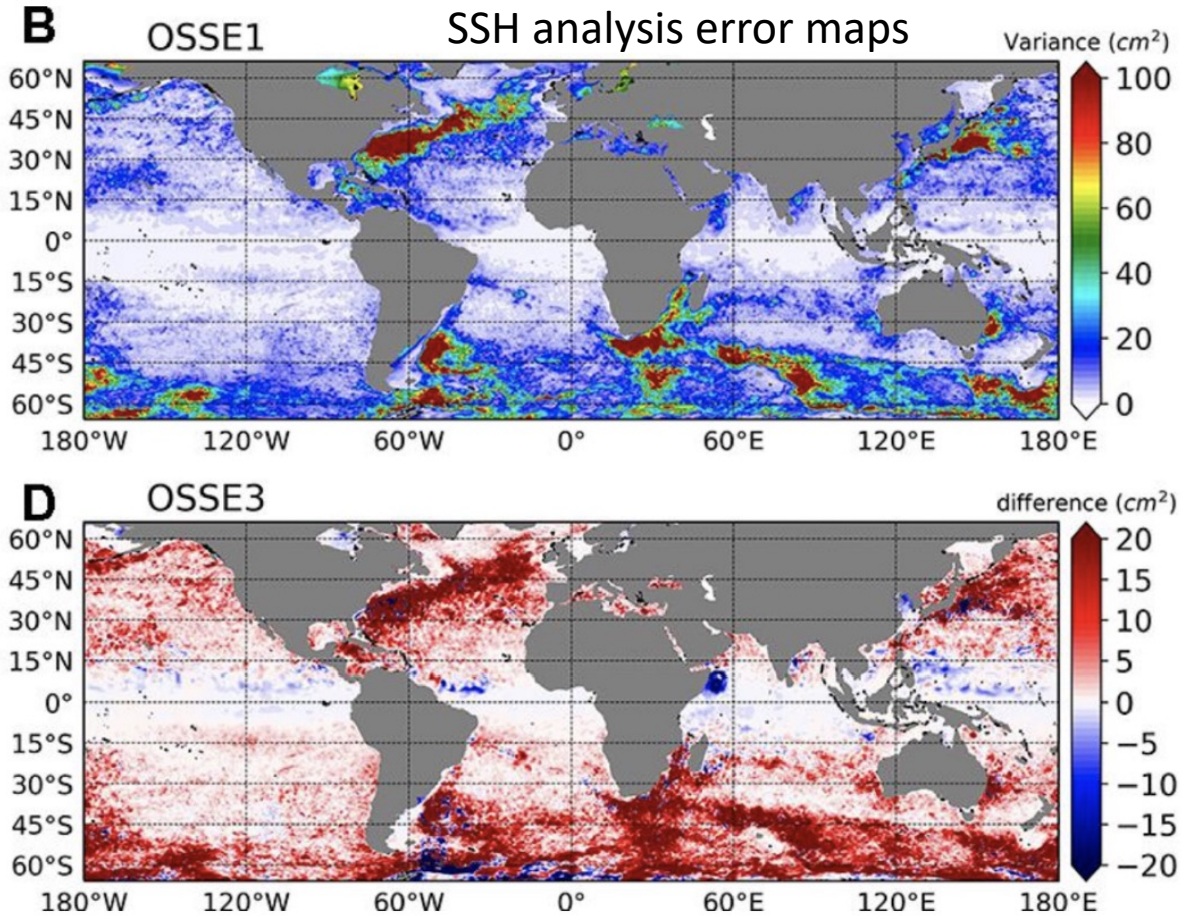
What excites me about the future…

Surface water and ocean topography mission – to improve understanding and forecasting of climate down to small scales

Theoretical coverage in 1 week



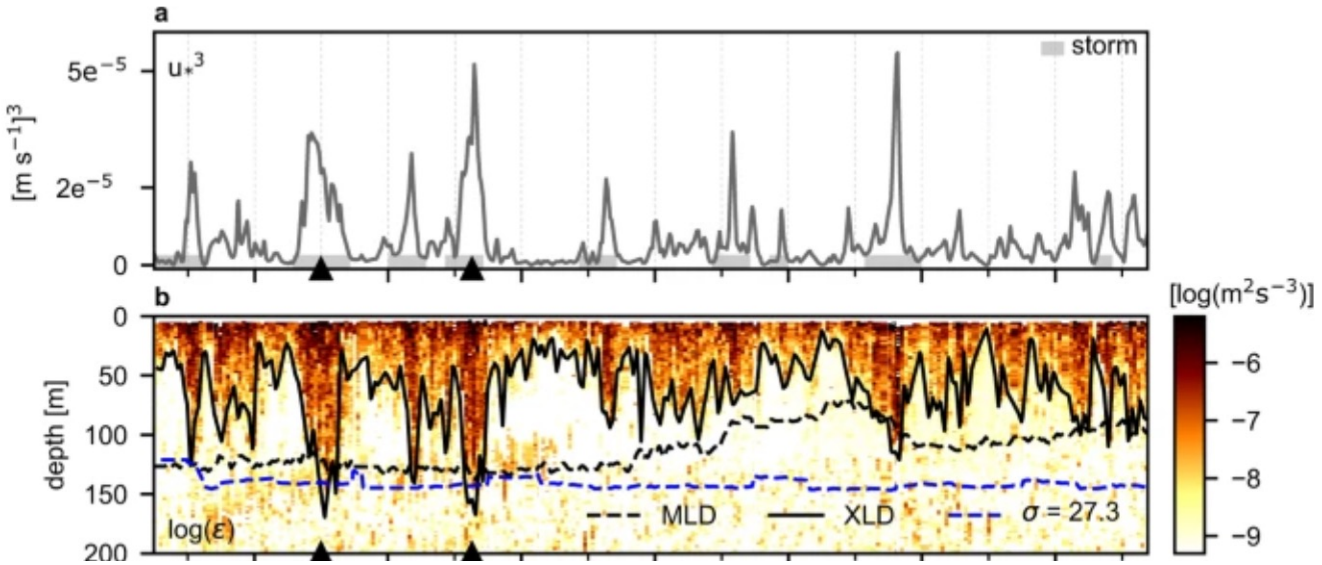
SSH analysis error maps



SWOT improves ocean analysis and forecasts in OSSEs (Tchonang et al. 2021).

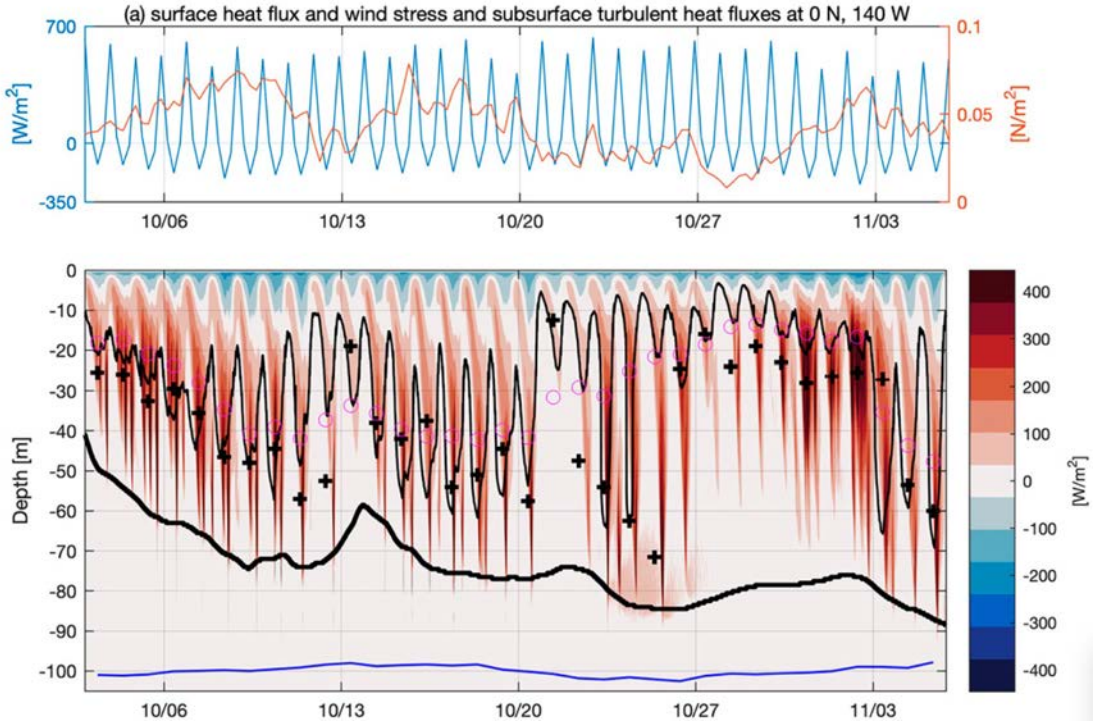
Increasing process observations from field experiments, autonomous sensors, simulations -> understanding derived from large data sets

Obs of winds and mixing over months in the subpolar Southern Ocean



Nicholson, Whitt et al. 2022

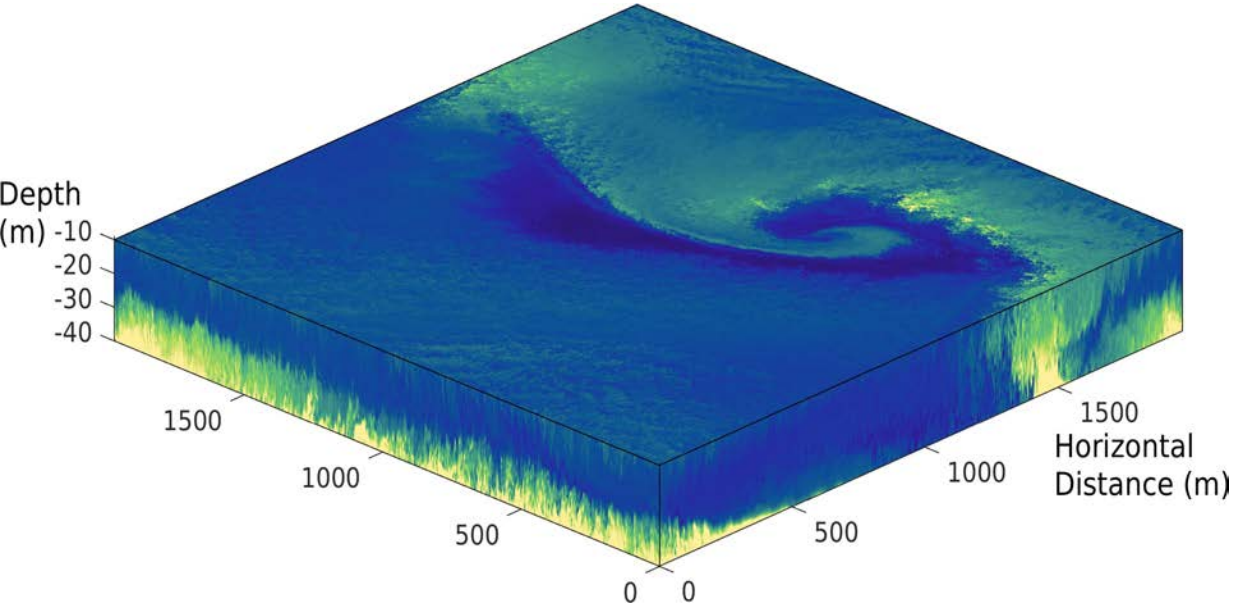
LES of turbulence modulated by tropical instability waves and weather in the tropical Pacific



Whitt et al. 2022

New applications of small-scale ocean information….

Physical-biogeochemical modelling & process observations to advance ocean CDR research



Fennel et al. incl. Whitt (2023)
Whitt et al. (2019)

Tracking/forecasting marine debris movements, helping MPA managers etc.

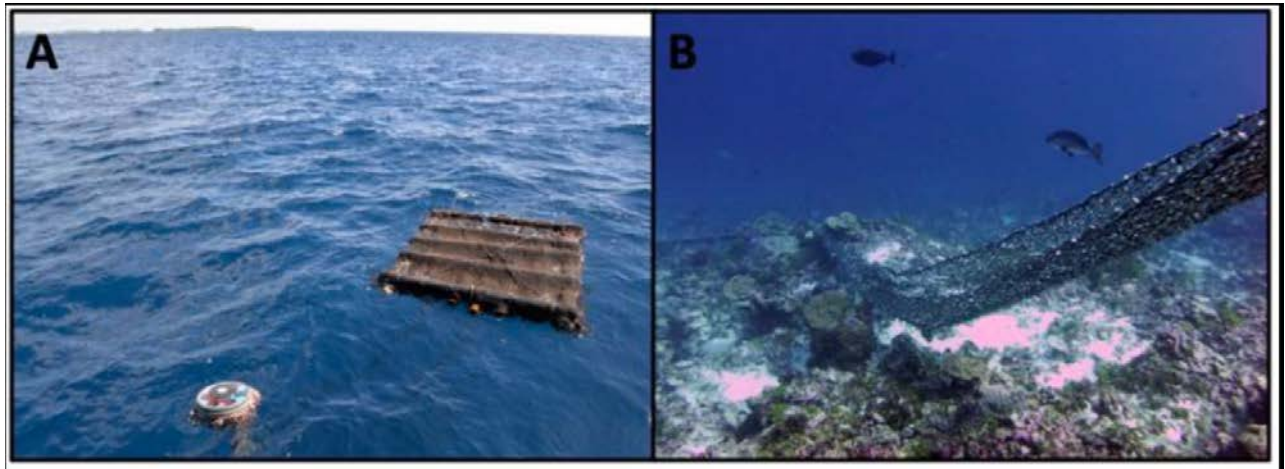


Figure 1: Drifting fish aggregating devices (dFADs) found at Palmyra Atoll National Wildlife Refuge. A) A typical raft style approximately 2x2 m is attached via rope to the transponder. B) Underwater view of grounded dFAD on coral reef. Photo credits: K. Pollock, The Nature Conservancy.