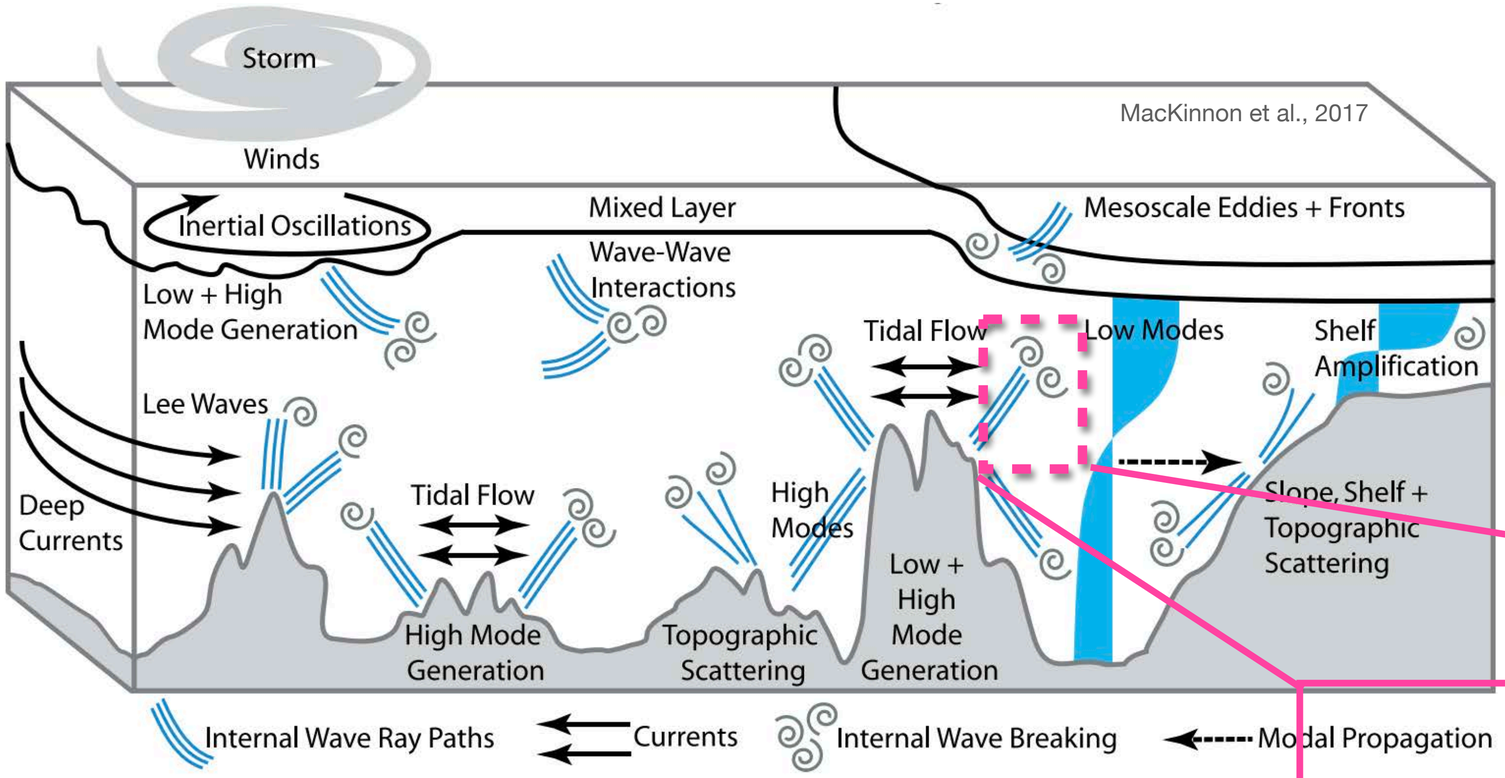
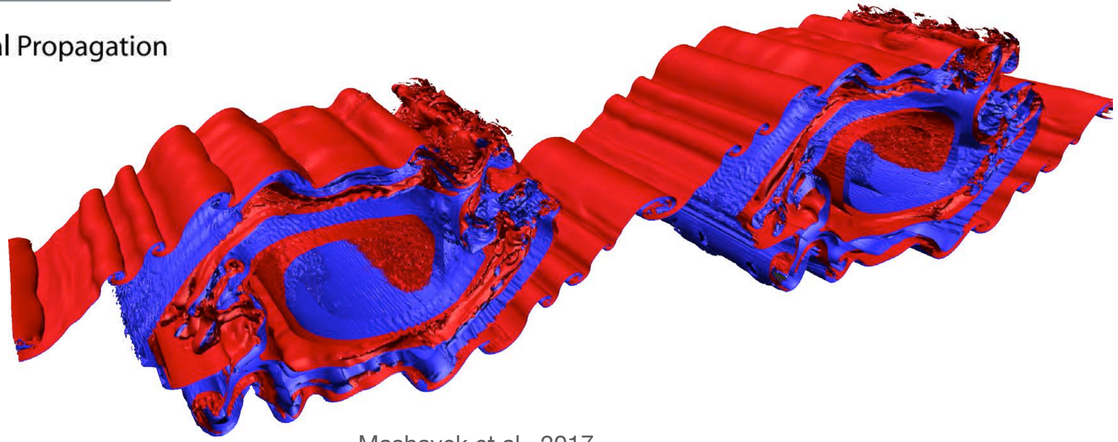
Fast to slow impacts of turbulent mixing

Laura Cimoli - University of Cambridge



- What is turbulent mixing?

- Internal wave-driven turbulence
- Homogenisation of properties (gradient erosion)
- Intermittent in time and space
- Small scale with global scale implications

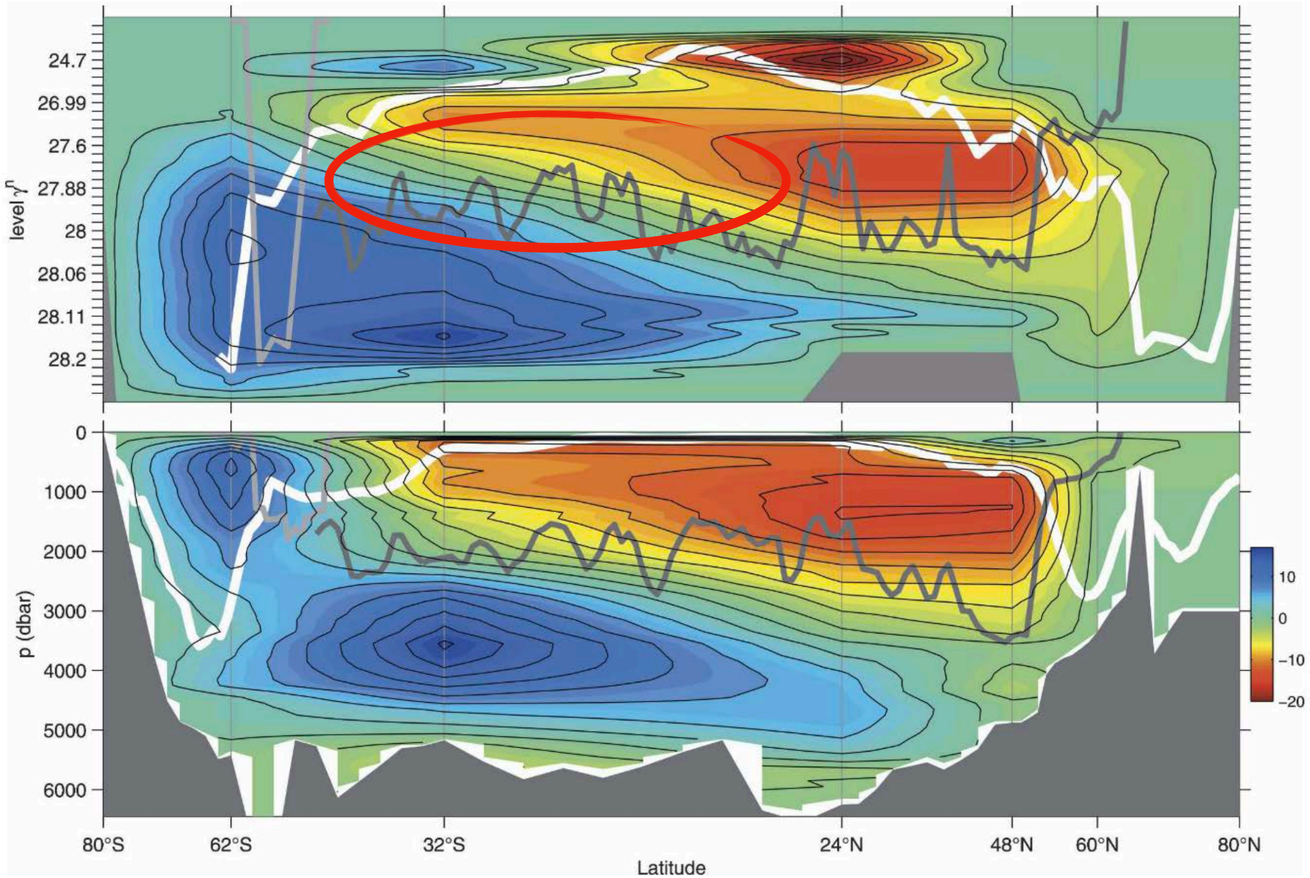


Mashayek et al., 2017

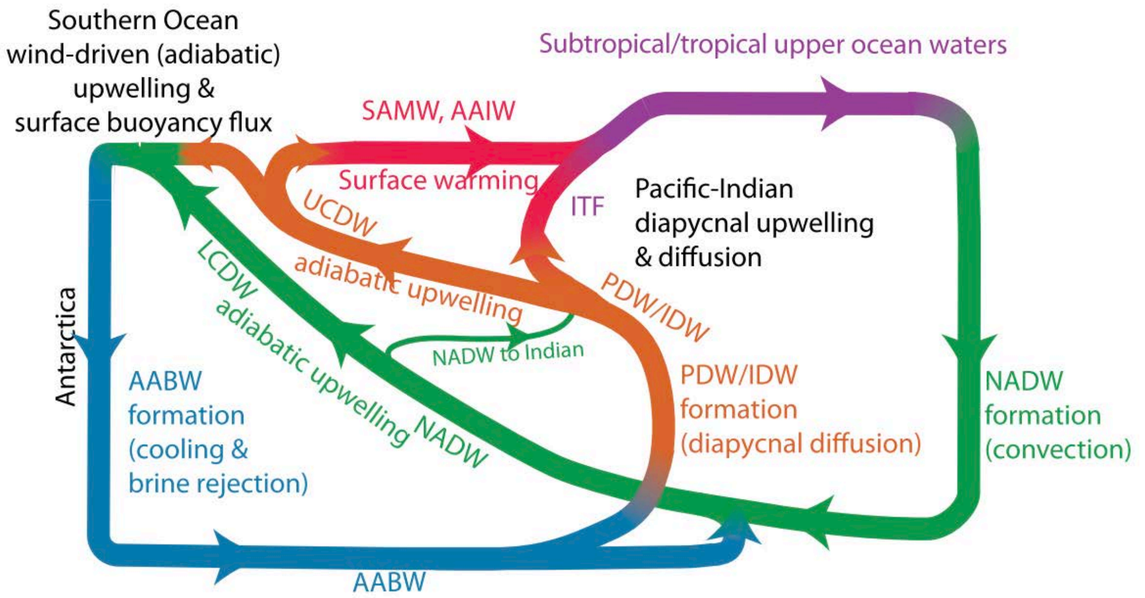
Outline

- Mixing and MOC (centennial to millennial)
- Mixing and tracers (decadal to longer)
- Mixing and BGC (annual to longer)

Turbulent mixing and the Meridional Overturning Circulation



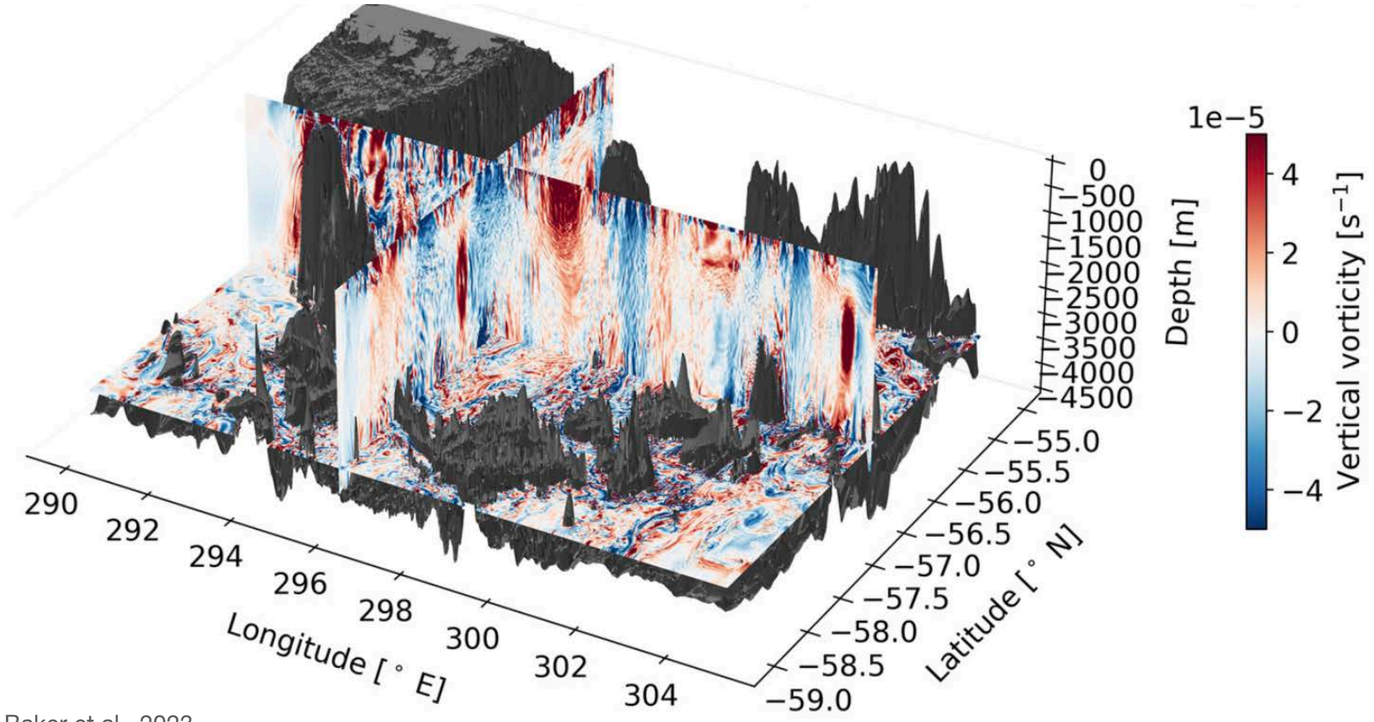
Lumpkin & Speer, 2007



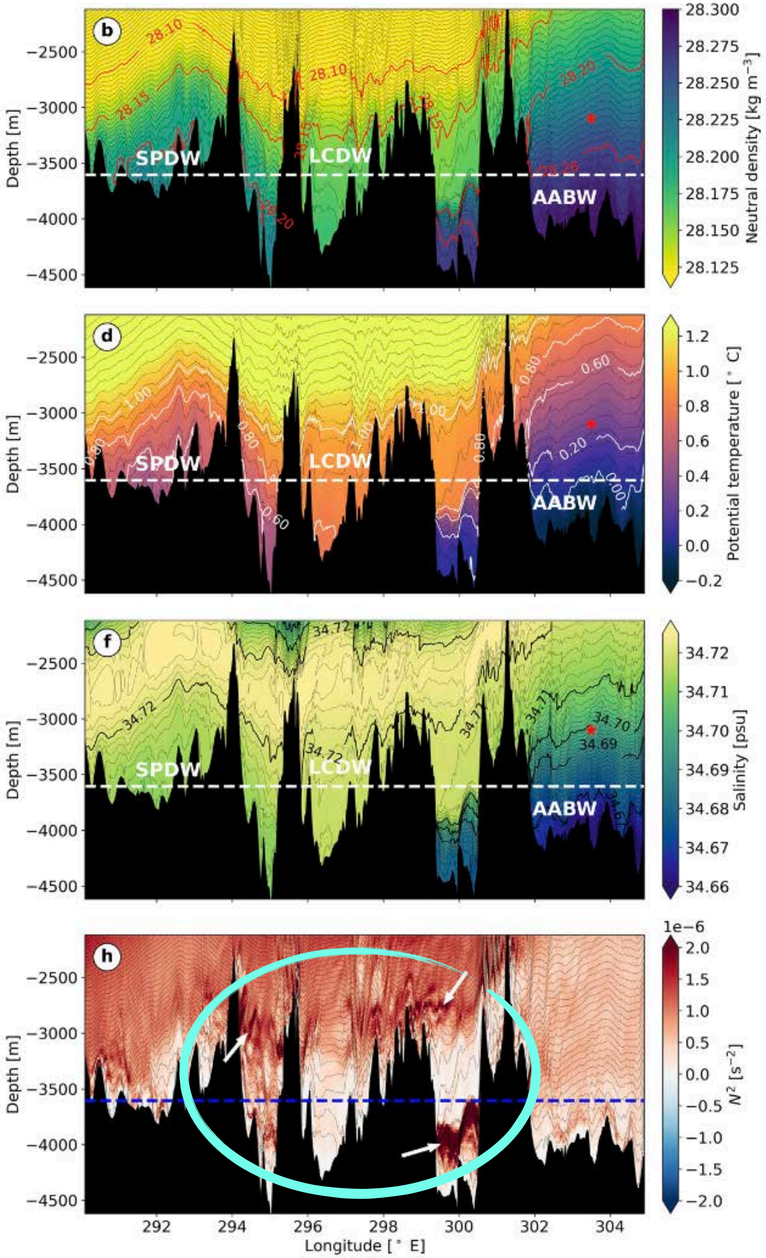
Talley 2013

Without deep mixing, the ocean would turn, within a few thousands years, into a stagnant pool of cold salty water *with equilibrium maintained locally by near-surface mixing and with very weak convectively driven surface-intensified circulation. (Wunsch & Munk, 1998)*

Turbulent mixing and the Meridional Overturning Circulation

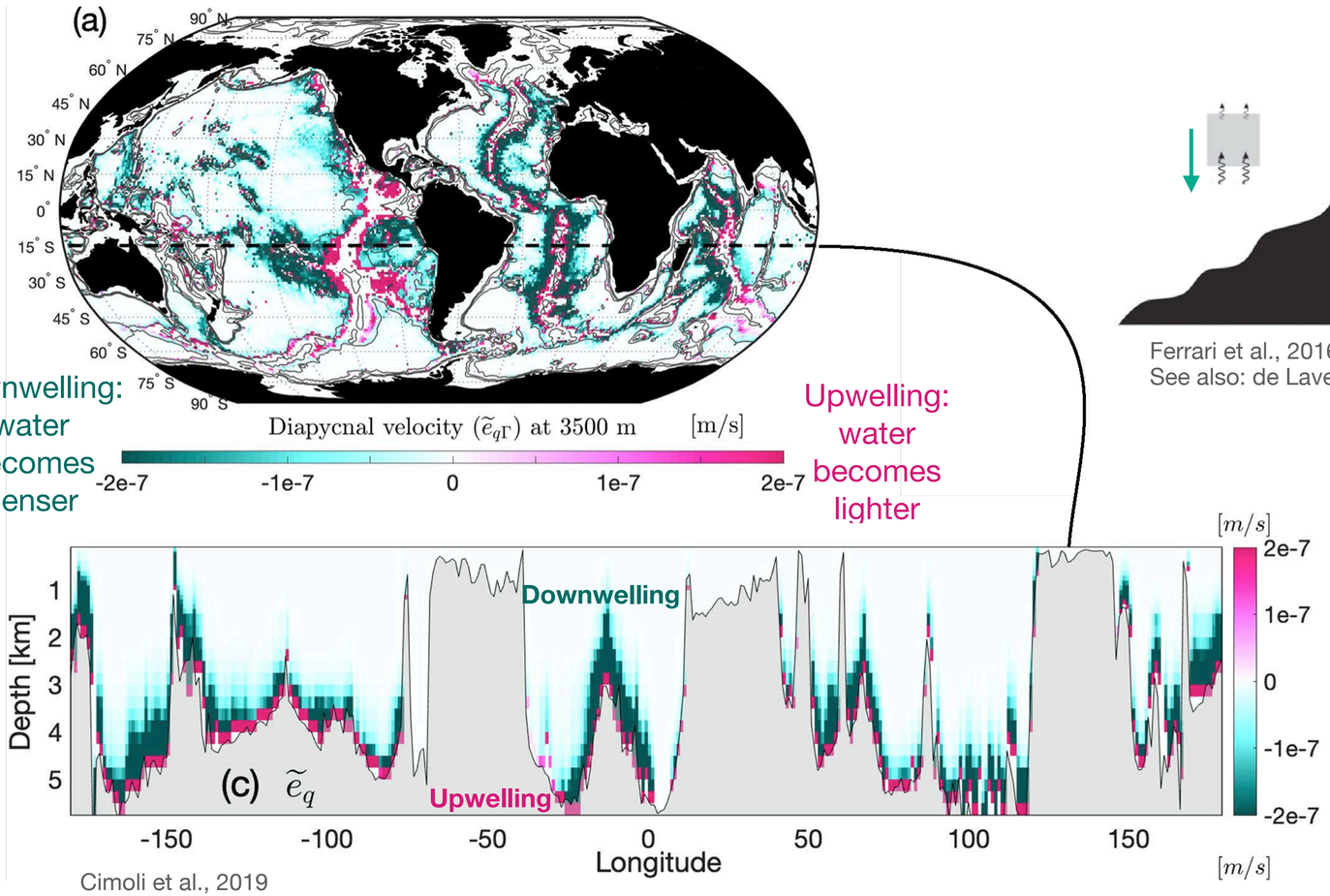


Baker et al., 2023

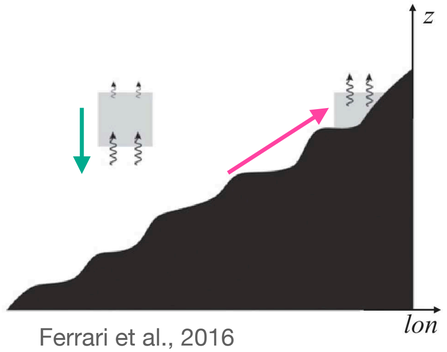


- Topographycally-induced mixing (ACC impinging on rough topography)
- Role of water masses sharp interfaces in modulating mixing

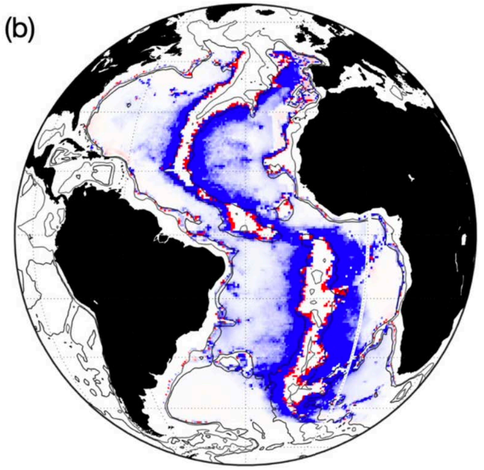
Turbulent mixing and the Meridional Overturning Circulation

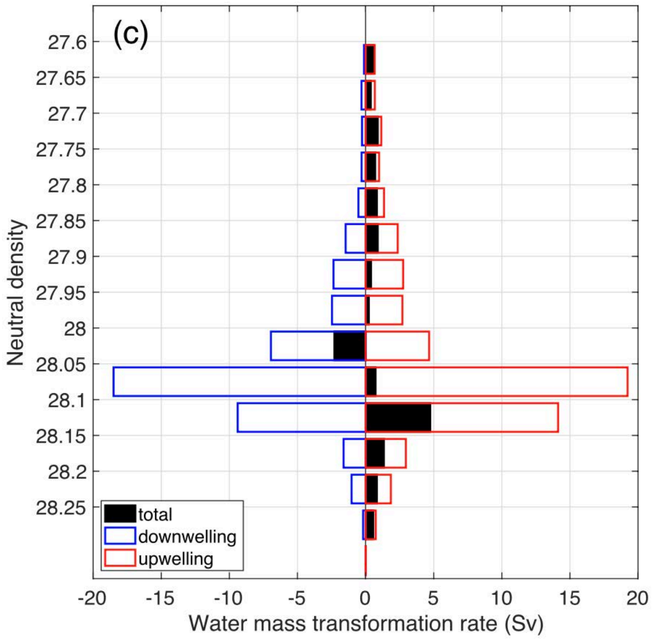


Cimoli et al., 2019



Ferrari et al., 2016
See also: de Lavergne et al., 2016

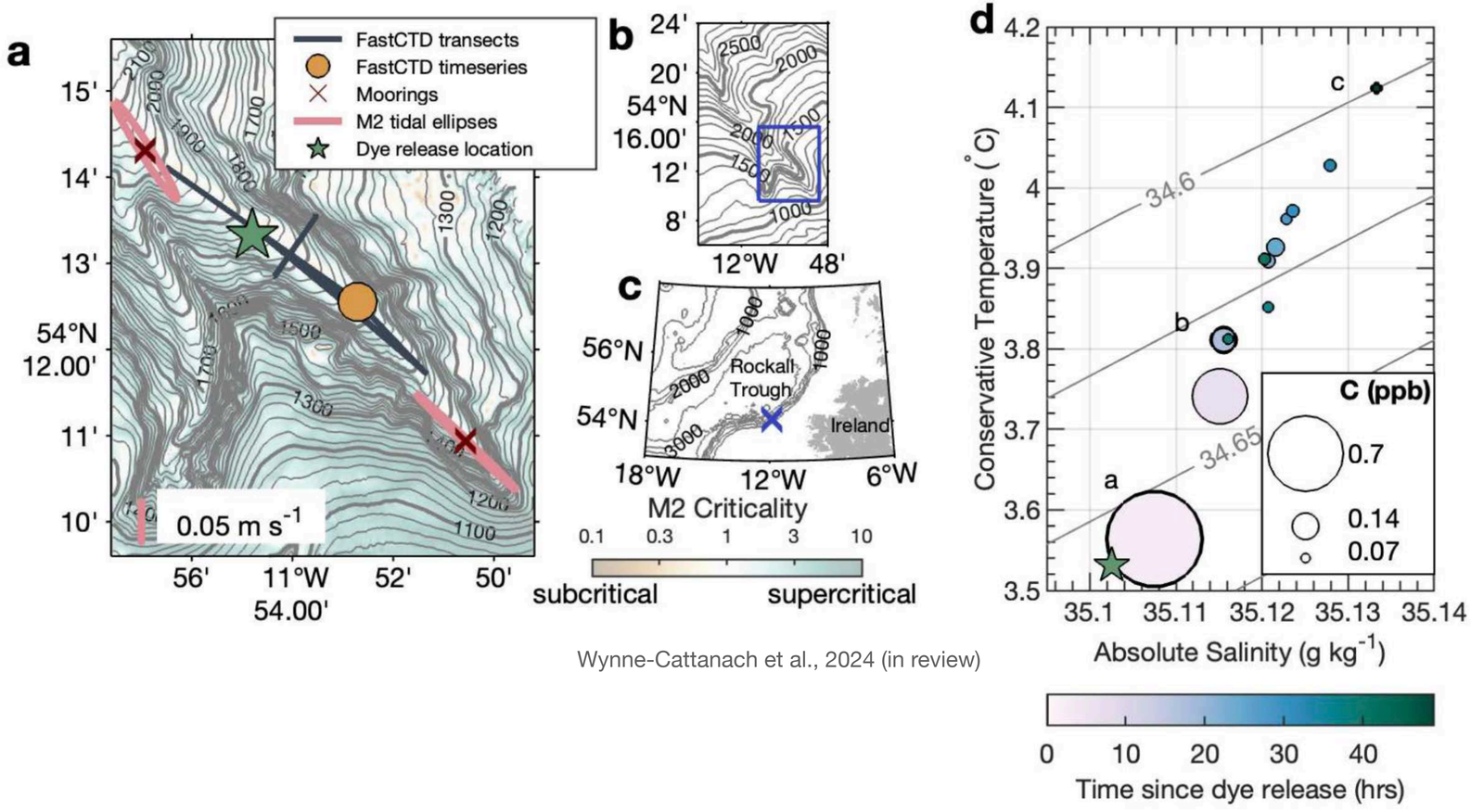




- Net upwelling VS local up/downwelling (over rough topography)

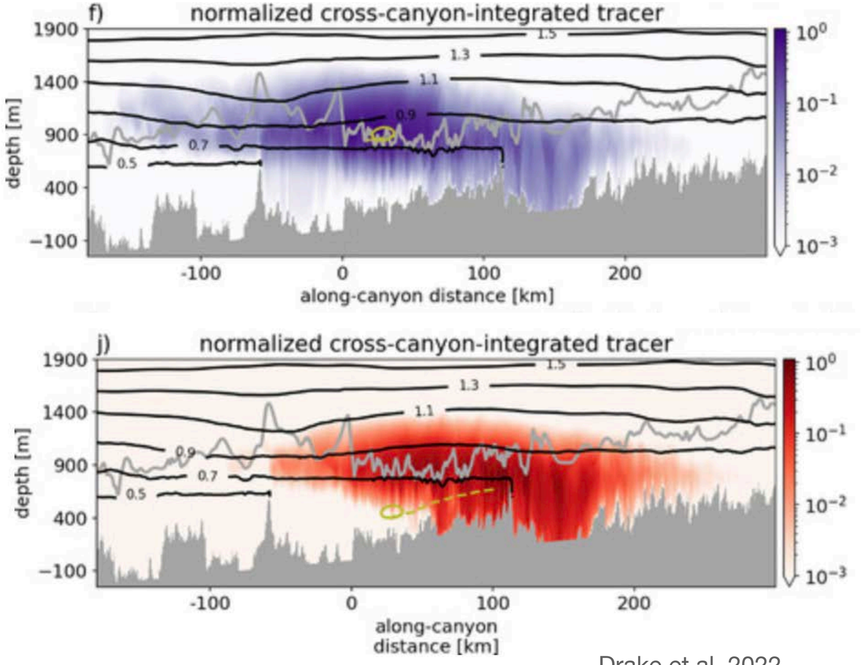
Turbulent mixing and the Meridional Overturning Circulation

Boundary Layer Turbulence (BLT) project: observational proof of along-boundary tracer upwelling



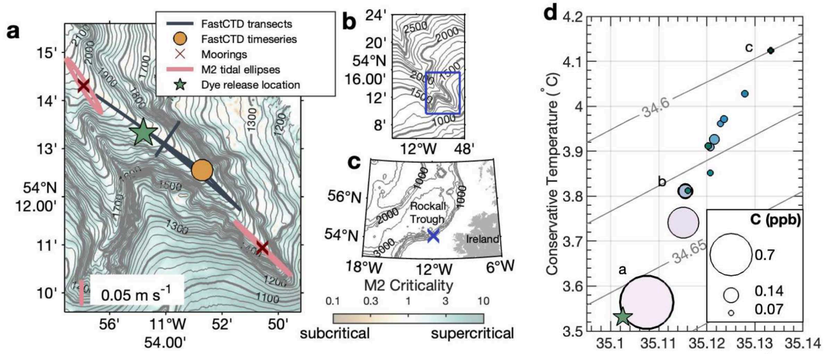
Wynne-Cattanach et al., 2024 (in review)

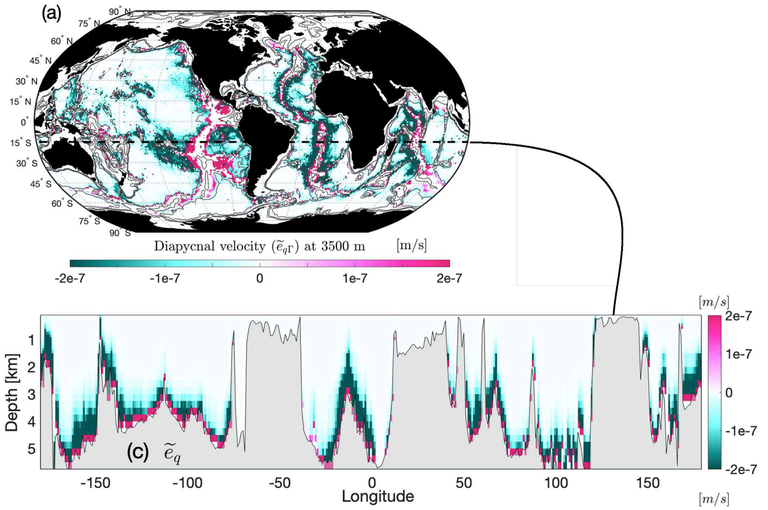
Boundary Layer Turbulence (BLT) project: results from realistic numerical simulations

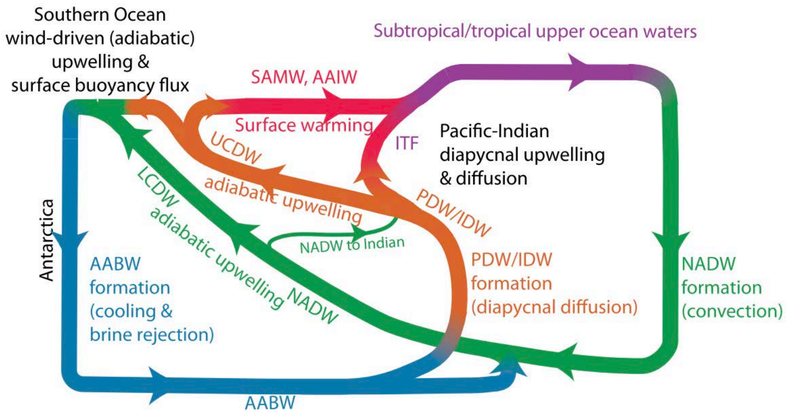


Drake et al, 2022

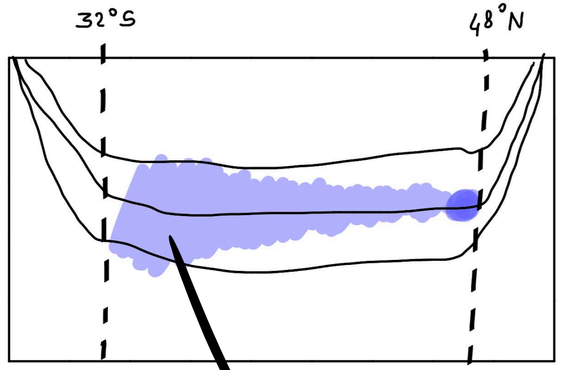
Turbulent mixing and the Meridional Overturning Circulation

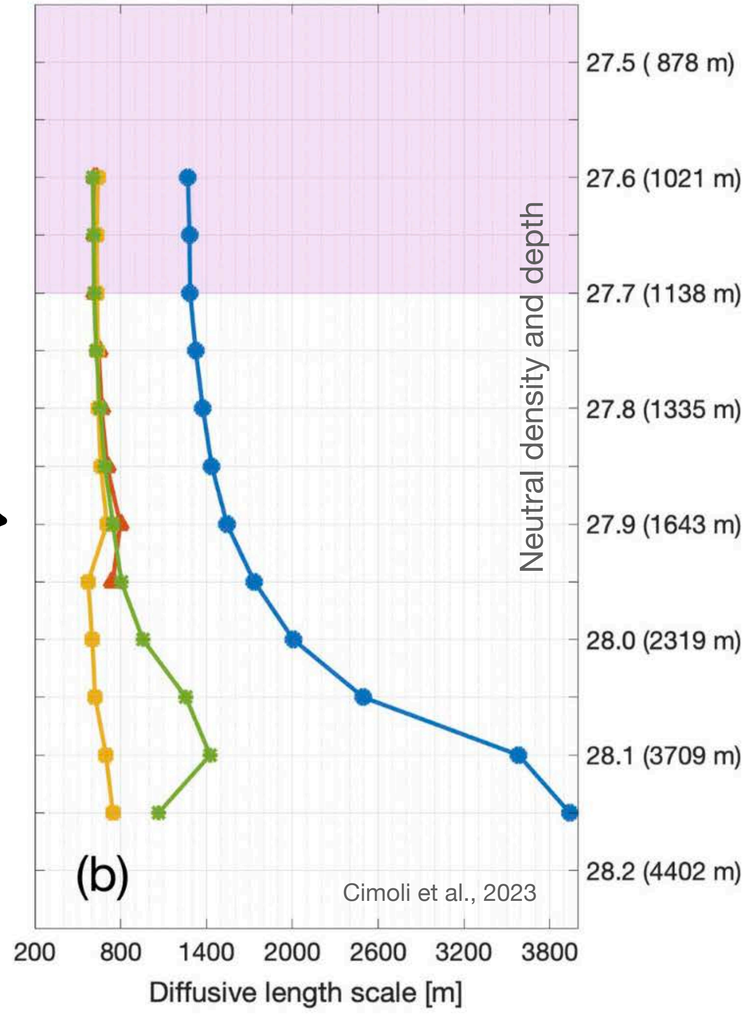




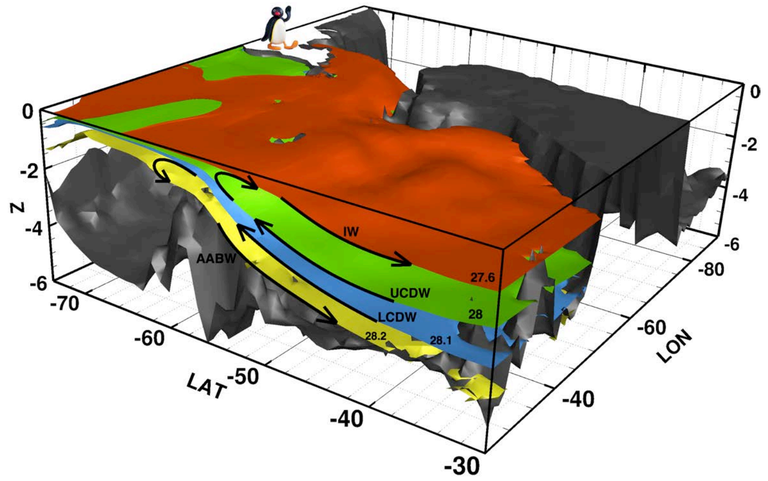


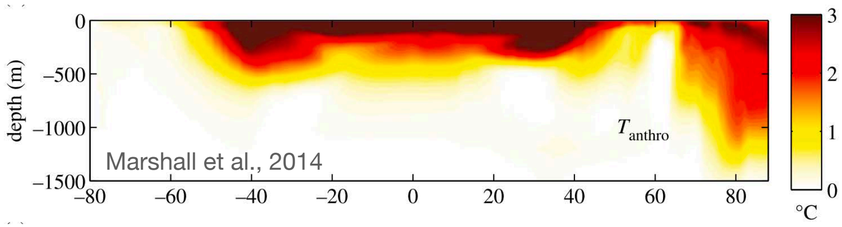
Turbulent mixing and tracers



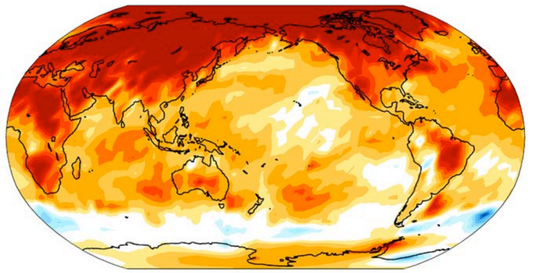


Implications for Southern Ocean pathways



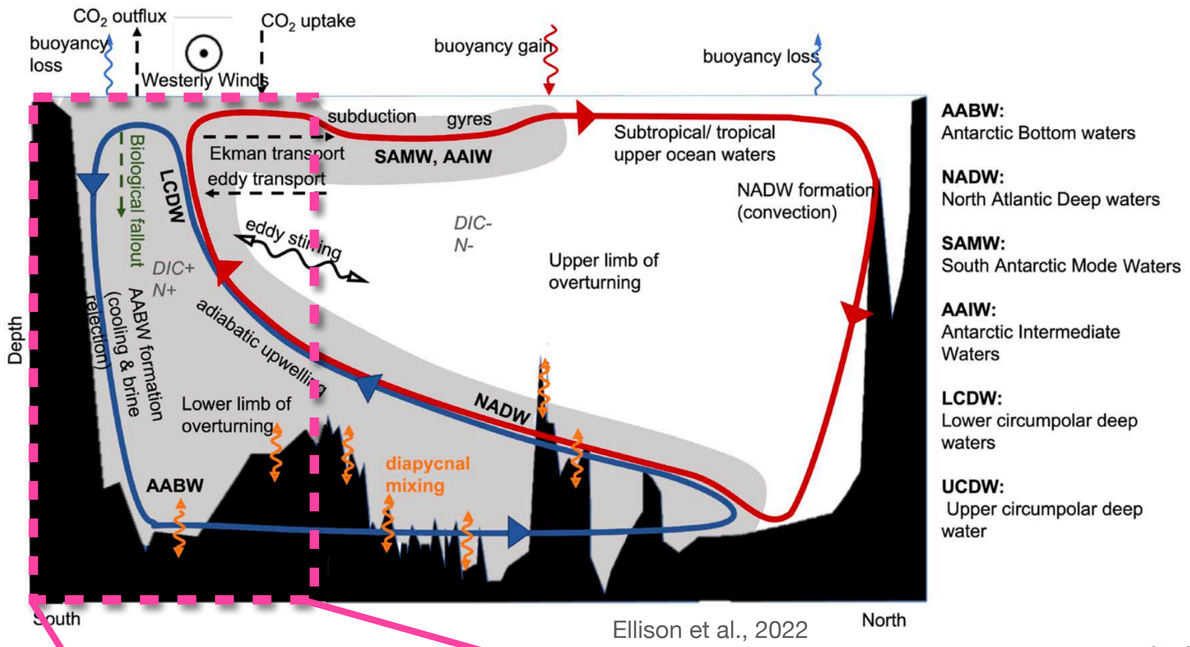


Surface temperature trends over the last 50 years



Armour et al., 2016

Turbulent mixing and BGC



AABW: Antarctic Bottom waters

NADW: North Atlantic Deep waters

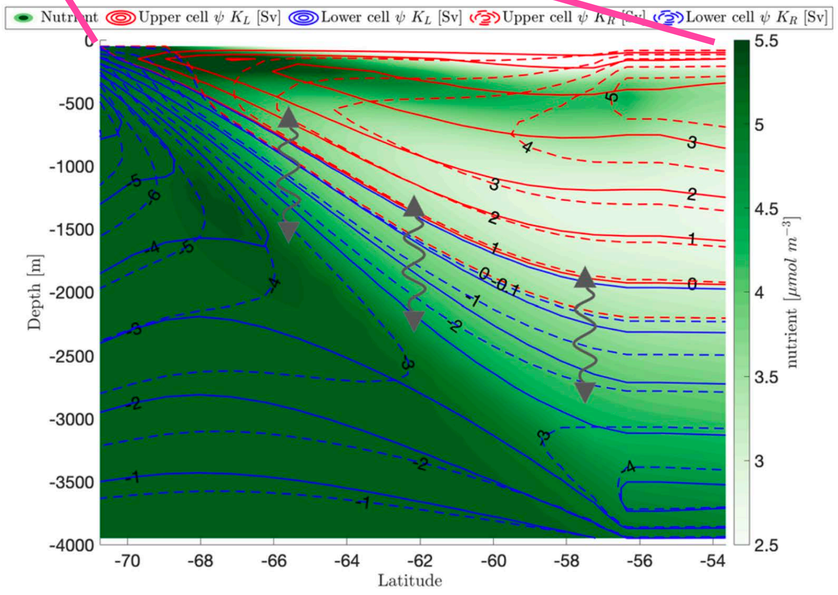
SAMW: South Antarctic Mode Waters

AAIW: Antarctic Intermediate Waters

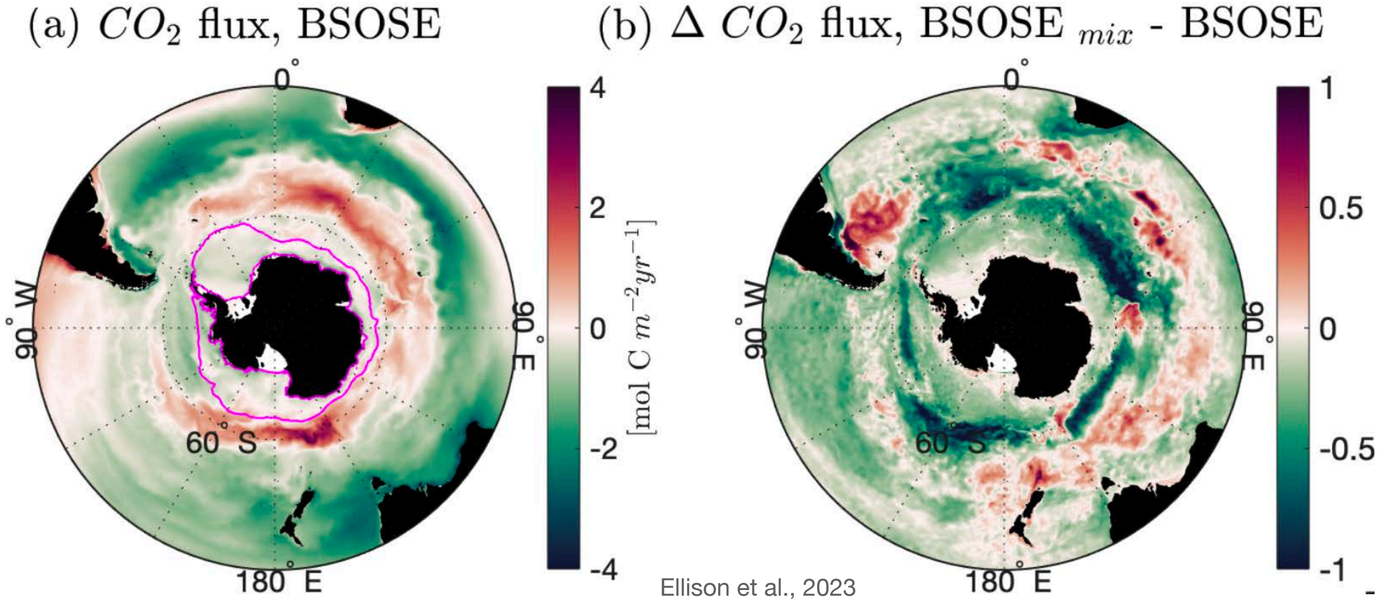
LCDW: Lower circumpolar deep waters

UCDW: Upper circumpolar deep water

Ellison et al., 2022

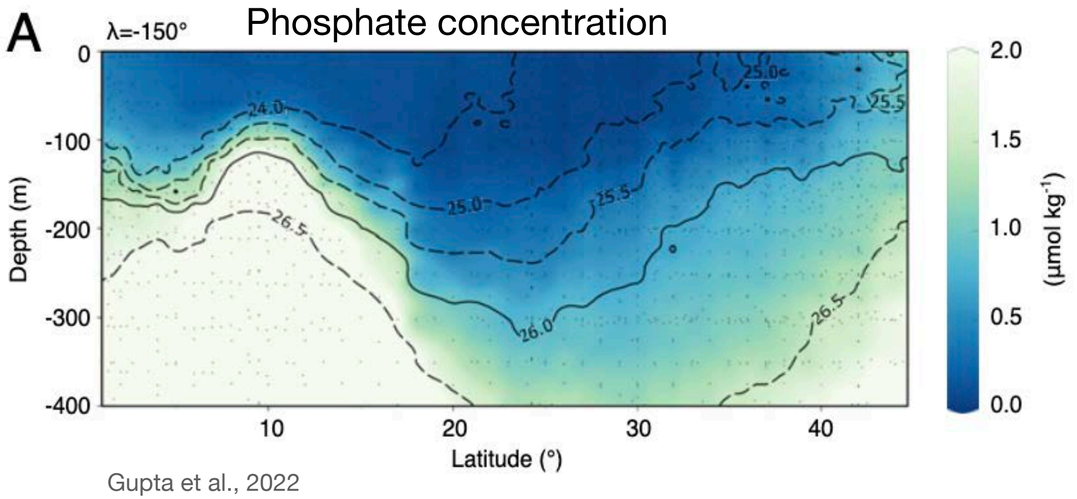


- Both idealised and realistic simulations confirm rapid effect of mixing on tracer distribution
- Realistic simulations: Mixing-driven changes to CO2 flux up to 40% over 6-year simulation
- Fast and slow timescales

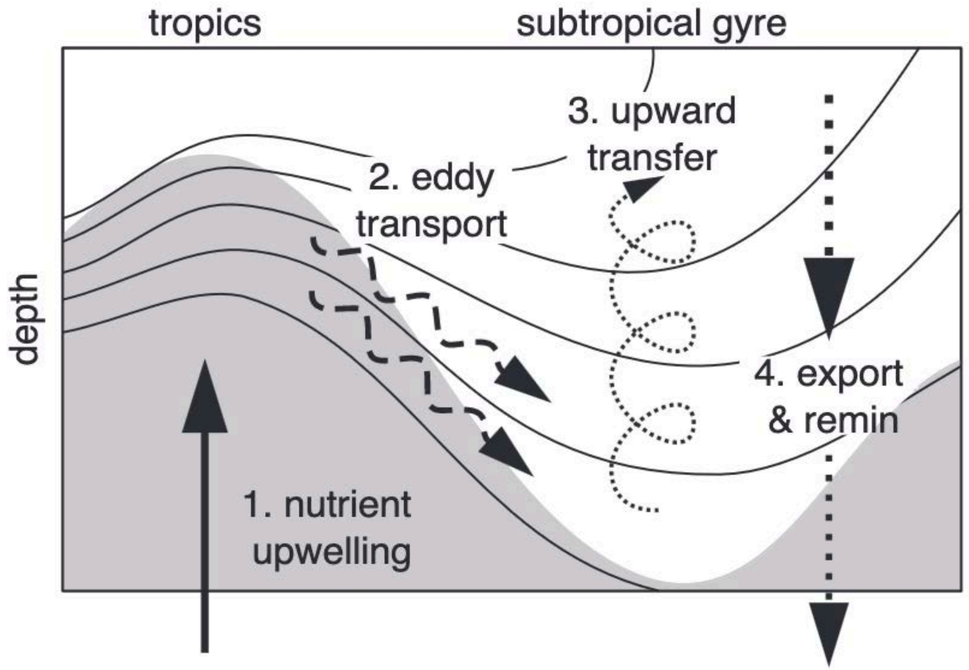


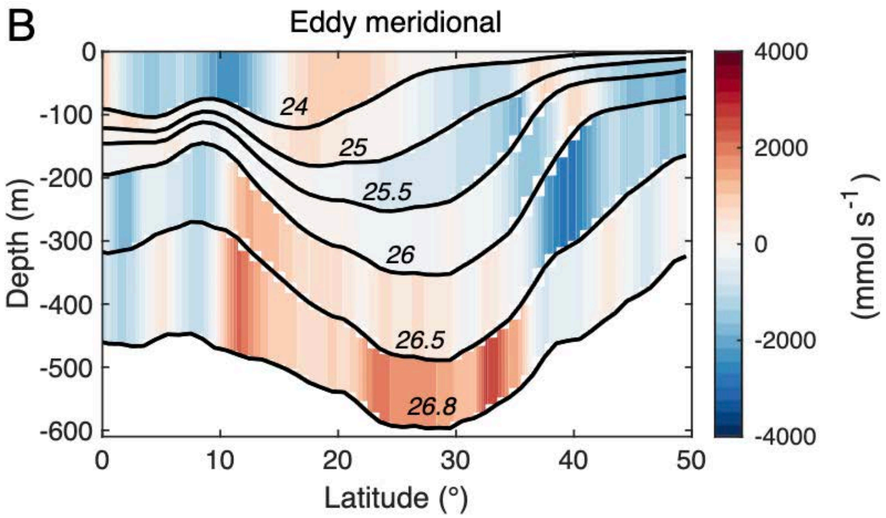
Ellison et al., 2023

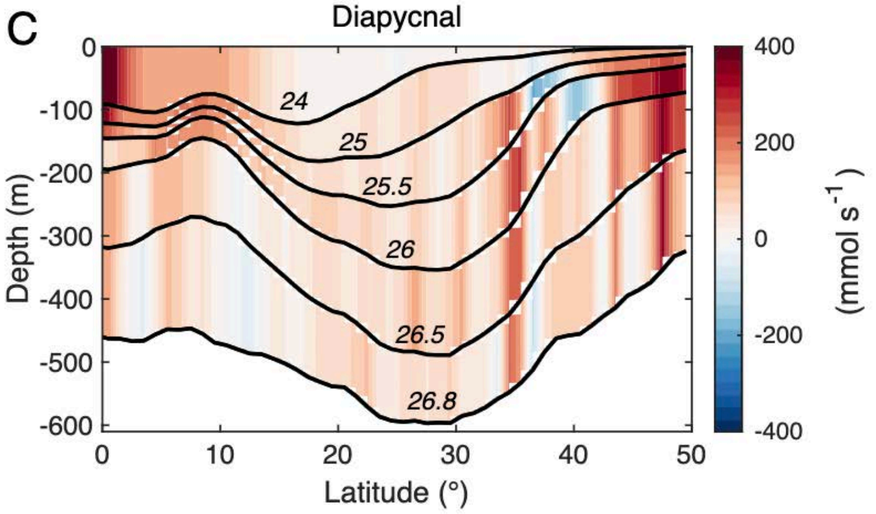
Turbulent mixing and BGC



Gupta et al., 2022







Observing and modeling turbulent mixing

Observations

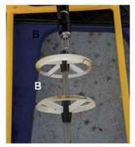
Turbulence Platforms (not Argo floats)

Nortek ADCP Signature 1000

Nortek Vector ADV

RSI VMP profiler

RSI Glider Microrider



Nobska MAVS

OSU mooring chipod

OSU Chameleon

Sea & Sun MSS profiler

DMO/RSI Wirewalker Microrider

WHOI HRP

SIO Epsilometer

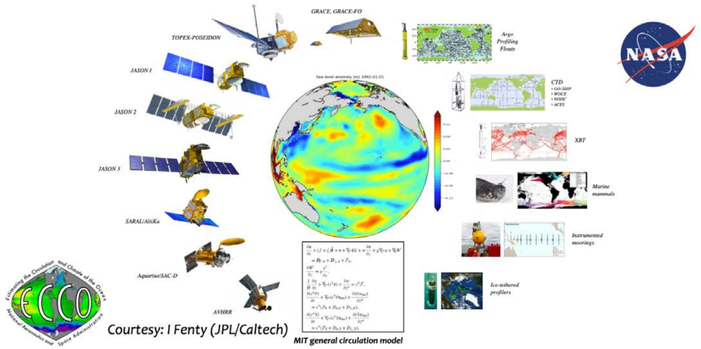
Le Boyer et al., 2023

- ArgoMix
- Tracer release experiments

Scaling up in space & time

State estimates

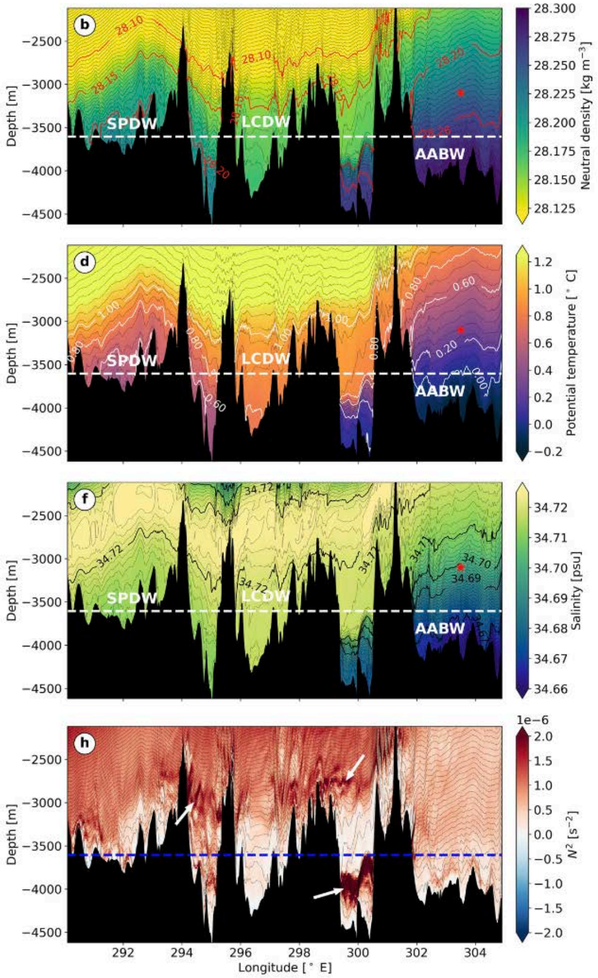
Challenge: Combine (1) incomplete diverse observations with (2) an imperfect model to provide our best, dynamically-consistent estimate of the ocean state for climate research



How can we improve mixing representation in ECCO (better observationally-constrained global models for regional downscaling)?

Can we use ECCO to provide meaningful large-scale estimates of ocean mixing (filling in the data gaps)?

Modeling



Observing and modeling turbulent mixing

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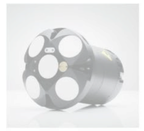

Nortek ADCP Signature 1000

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RSI VMP profiler

RS

OSU mooring chipod

OSU Chameleon

Sea & Sun MSS profiler

DMO/RSI Wirev Microrider

- ArgoMix
- Tracer release ex

Scaling up in spac

OBSERVATIONS

SCALING UP IN TIME & SPACE

DATA ASSIMILATION

VALIDATION AND STATISTICS

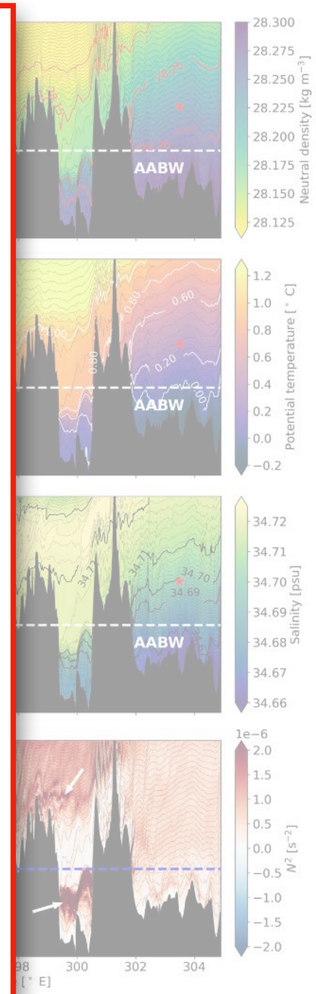
ECOSYSTEM SCALE

INTEGRETED SYSTEM

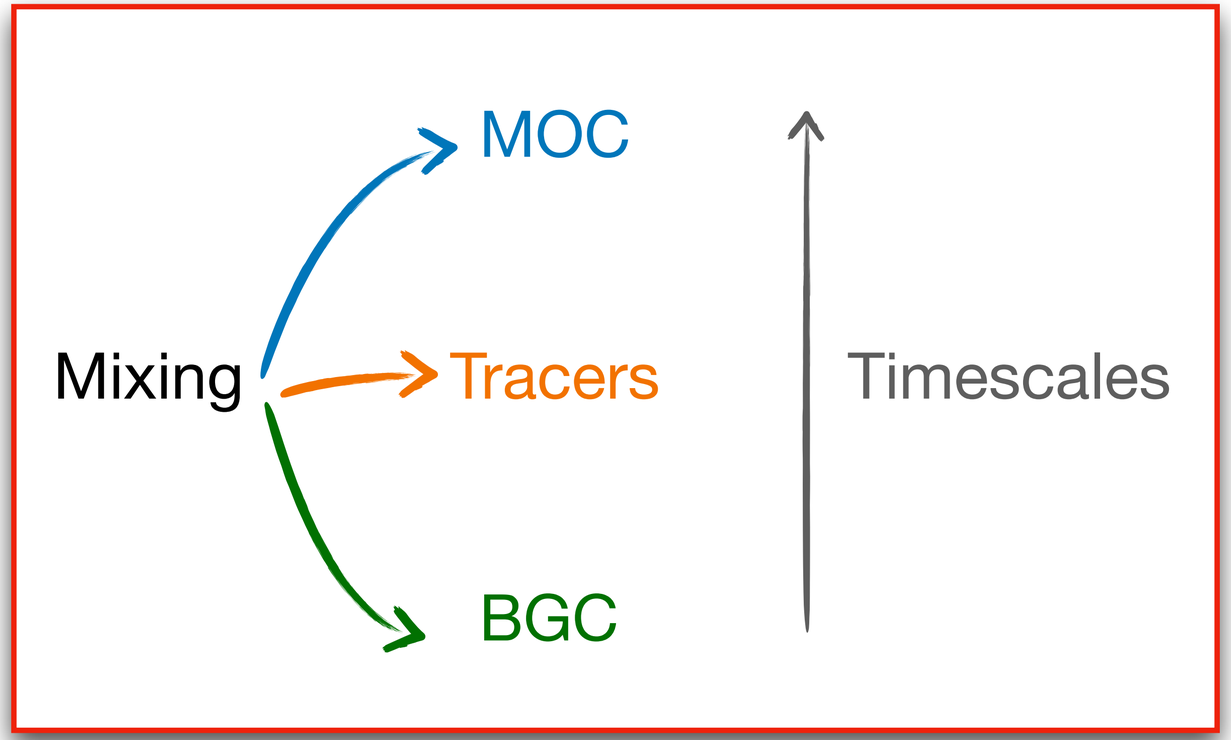
NUMERICAL MODELS

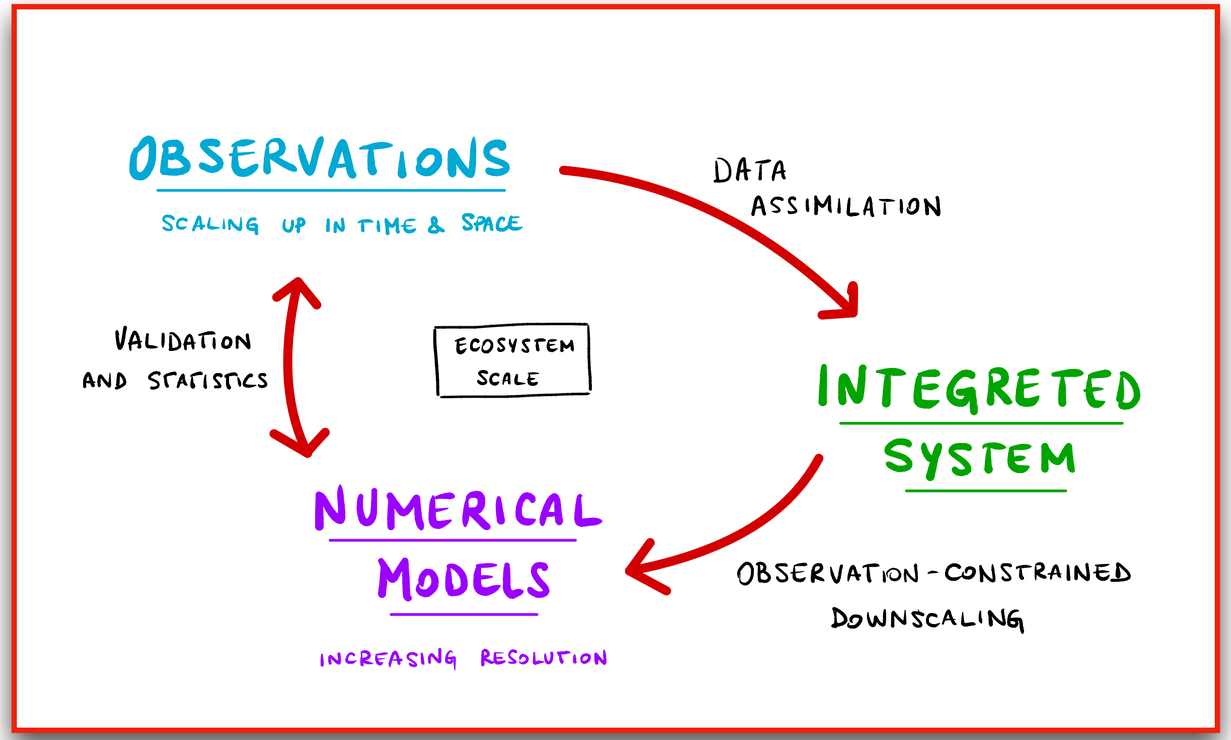
INCREASING RESOLUTION

OBSERVATION-CONSTRAINED DOWNSCALING



Summary


MOC
Mixing
Tracers
BGC
Timescales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