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Influence of surface wave mixing on oceanic biogeochemistry

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Presented by:

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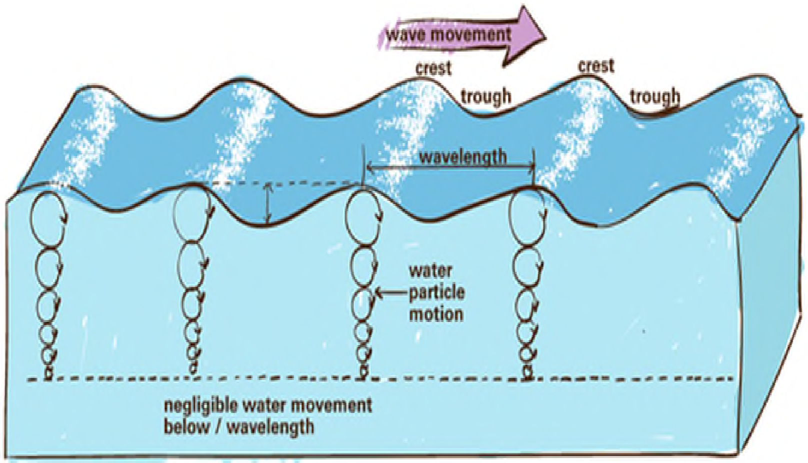
Two main mechanisms of turbulence injection by surface waves in the upper ocean

(a) Wave breaking

(source: NOAA http://www.nesdis.noaa.gov/news_archives/wod_2013.html)

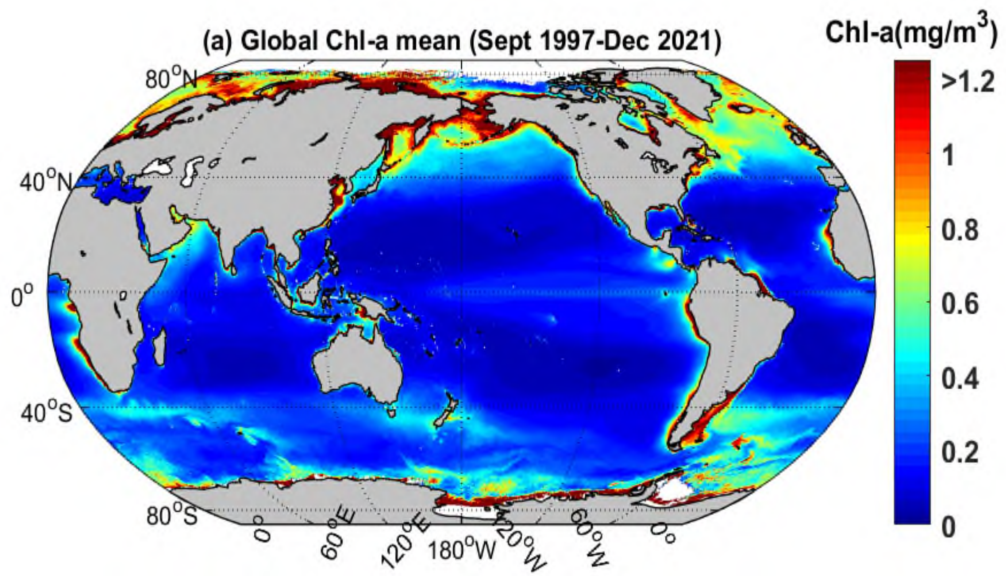
(b) Wave orbital motion



(source: https://wavestides.weebly.com/wave-motion.html)

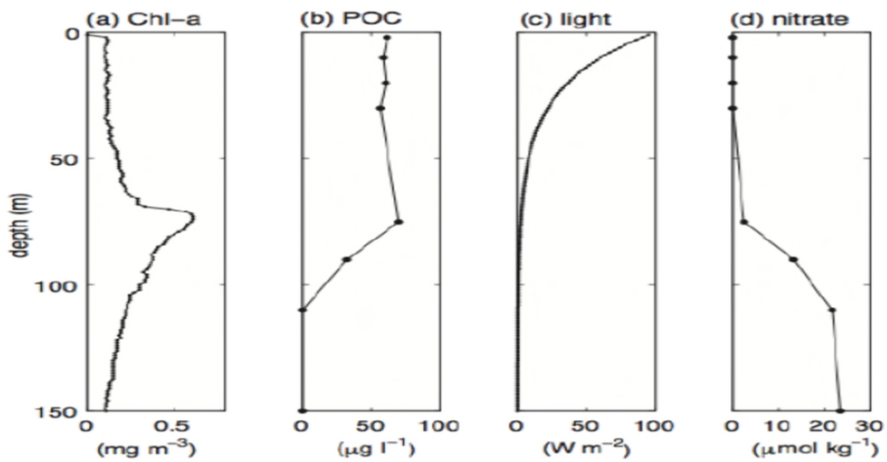
- ❑ **Turbulent injection depth for wave breaking is limited at the scale of wave height (Babanin, 2006).**
- ❑ **For wave orbital motion, it can reach to a scale of wavelength (say 100 m) and can mix through thermocline.**

Marine Phytoplankton (The Ocean Forest)



Note: Chl-a map is generated using ESA's OCCCI ocean color data

(b) Depth profile of Chl-a, POC, light and nitrate in the ocean



Courtesy: INCOIS,India and Kaempf, Jochen & Chapman, Piers. (2016)

- Living **Essential Climate Variable (ECV)**
- Two main limiting factors (**nutrients** and **light**)

What are the influence of surface waves on these BGC profiles?

Research Motivation and Objectives

What are the influence of surface wave mixing on oceanic biogeochemical parameters?

- ❑ Wave breaking (scale limited to wave height)
- ❑ Wave orbital motion (scale upto wavelength and can mix through thermocline, **Babanin 2006**)

- ❑Wind and wave activities are prominent in Southern Ocean.
- ❑Previous studies on the influence of wave induced mixing on the upper ocean such as SST and MLD improvement (Qiao et al. 2010, Babanin et al., 2009, Walsh et al., 2017).
- ❑**How may changing wave climate impact oceanic biogeochemistry in the near future?**

Objective:

Study of wave induced turbulence effect on oceanic biogeochemistry using a global ocean sea ice model MOM5-SIS-TOPAZ.

MODEL DESCRIPTION AND EXPERIMENTAL SETUP

Model description

- Global ocean sea ice model MOM5-SIS-TOPAZ
- Components
  - **Modular ocean model** (ocean)
  - **GFDL Sea Ice Simulator** (Ice)
  - **Tracers of Ocean Phytoplanktons with Allometric Zooplankton** (TOPAZ, biogeochemical module)
- Horizontal resolution
  - 1° resolution
- Vertical resolution
  - 50 levels (5 m to 5316 m)

Experimental setup

- MOM5-SIS-TOPAZ test configuration is downloaded from GFDL's repository.
- Input forcings : JRA55-do
- Wave input: ST6 WW3 hindcast
- Spin up period: 1981-2000 (20 years)
- Analysis period: 2001-2010 (10 years)

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Parameterization of surface wave mixing (unbroken waves) in MOM5

- k-epsilon mixing scheme
- The parameterization of wave induced mixing is taken from **Ghantous and Babanin, 2014 and Walsh et al., 2017.**
- The wave induced mixing is added as an additional production term in the mixing scheme.

$$P = \boldsymbol{\nu}(M^2 + \boldsymbol{\alpha} N^2) + W$$

$$W = bk\left(\frac{\omega H_s}{2}\, e^{kz}\right)^3$$

Where, **P** is the shear production term,

$\boldsymbol{\nu}$ is the turbulent diffusivity of momentum,

M is the shear frequency,

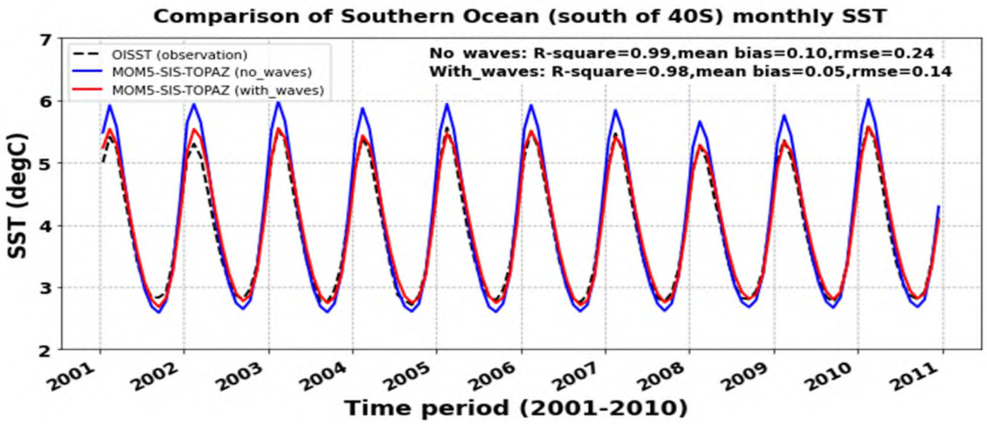
$\boldsymbol{\alpha N^2}$ is the parameterization of internal wave breaking, and

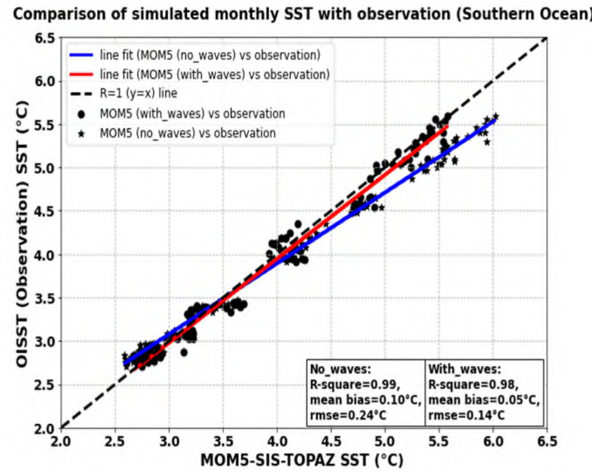
W is extra turbulence by wave induced mixing.

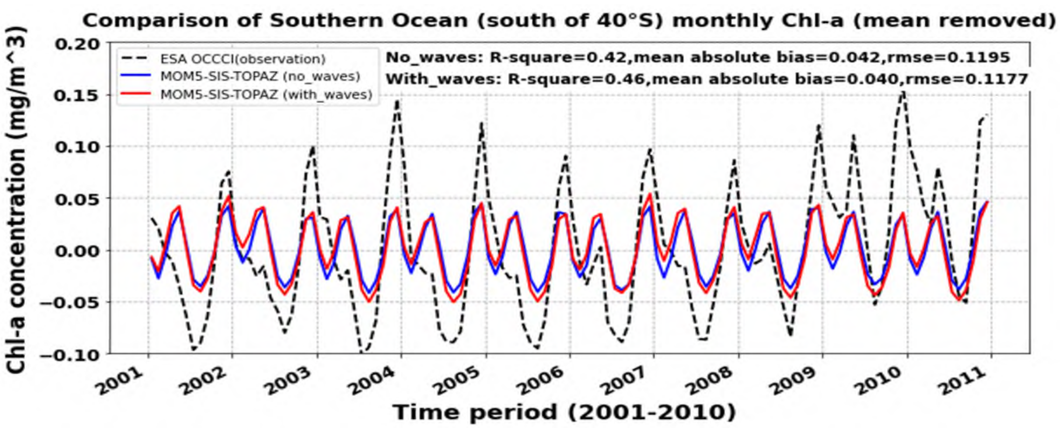
The constant **b** is the empirical constant equals to 0.0014 **(Young et al., 2013).**

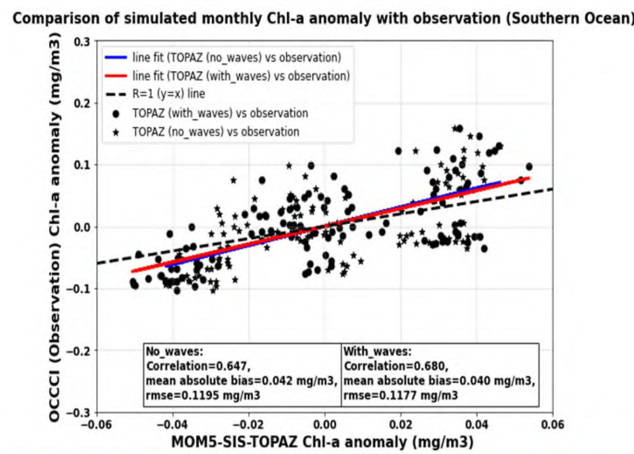
- Significant wave height (Hs) and peak frequency (fp) data are taken from ST6 WW3 hindcast (**Liu et al., 2021**)

Validation of simulated Southern Ocean SST and Chl-a

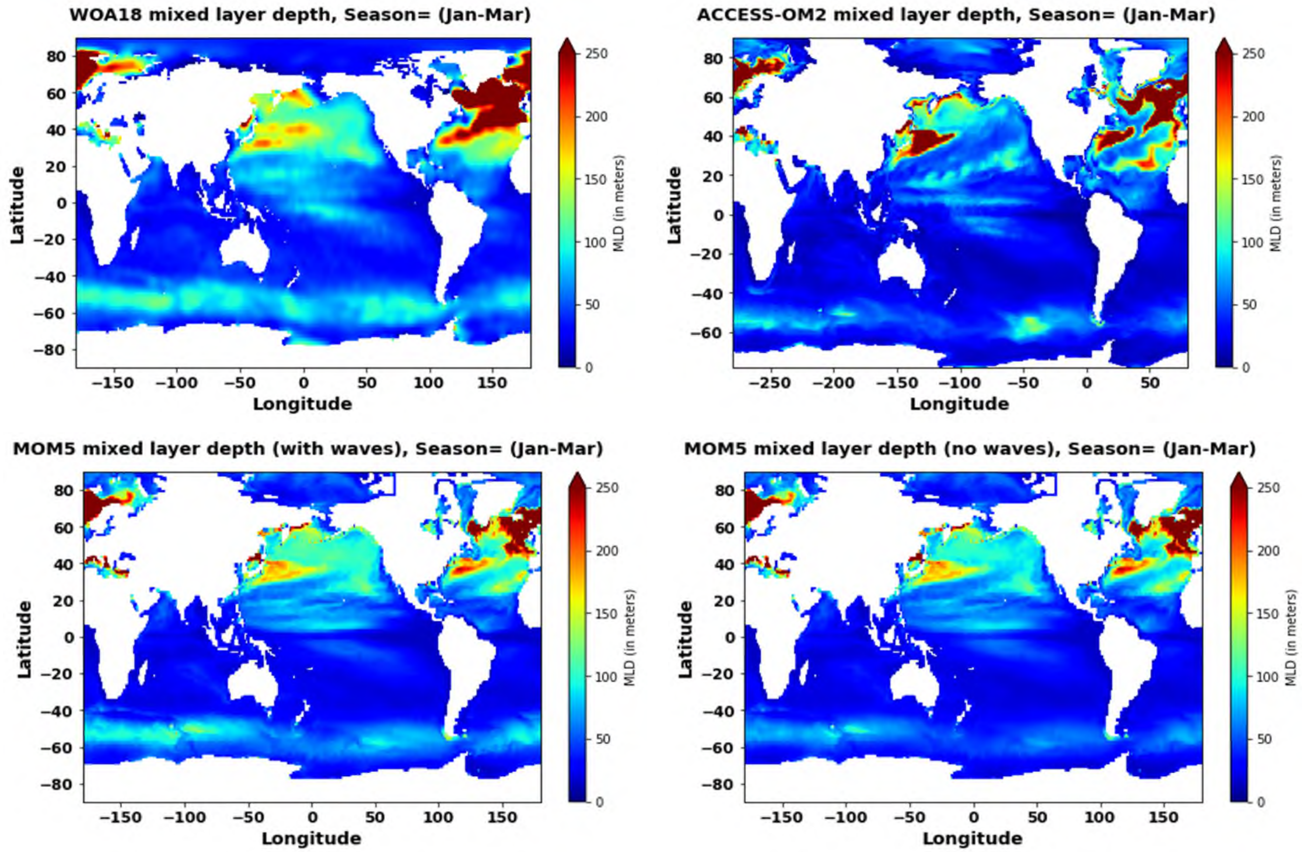






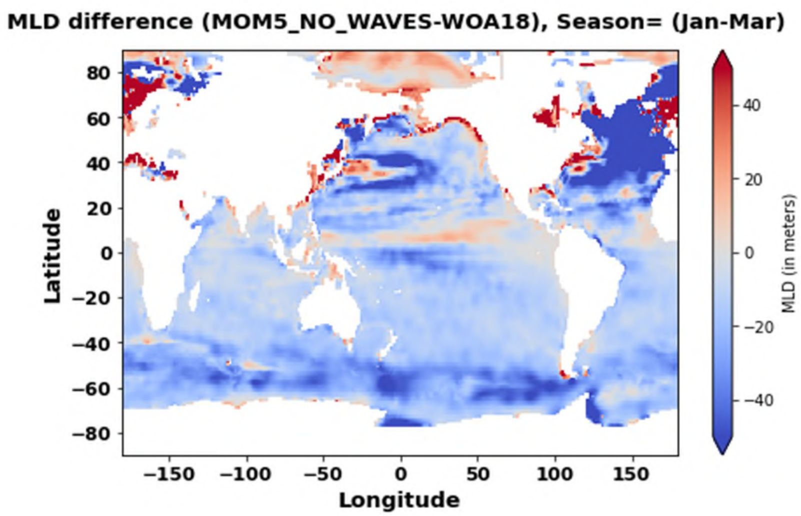


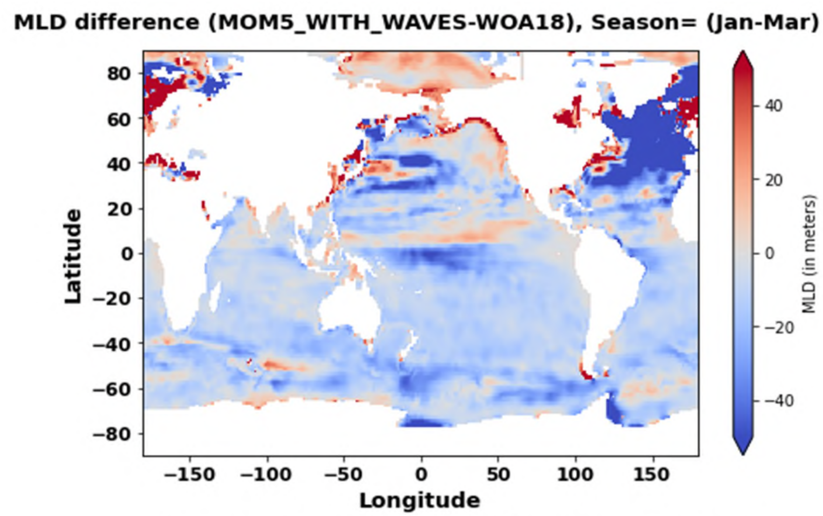
Comparison of simulated mixed layer depth (MLD) with observation data (WOA18)

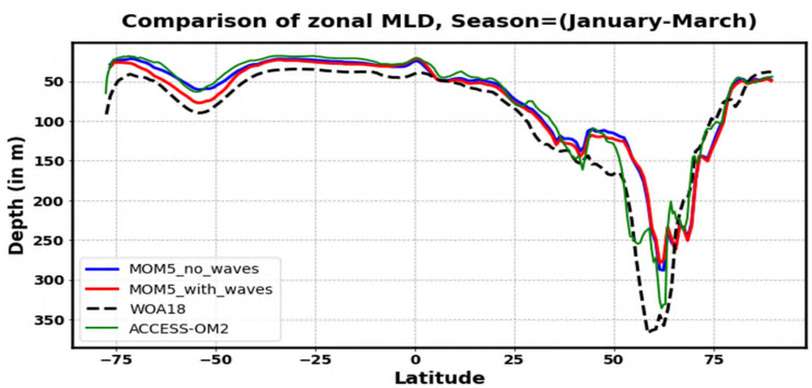


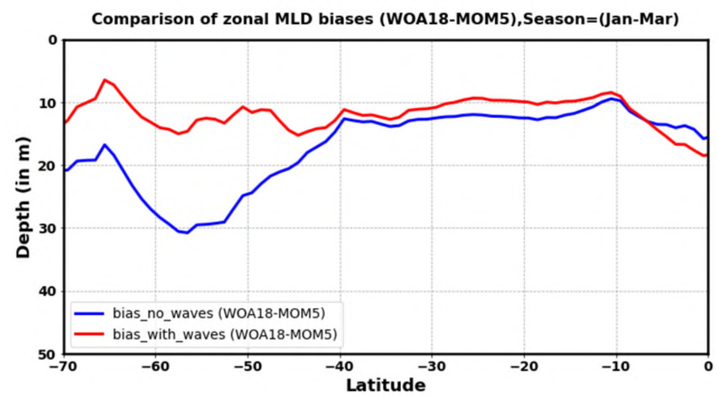
- ❑ Underestimation of MLD in the Southern Ocean during austral summer is common in most ocean models.
- ❑ MLD is enhanced in the Southern Ocean and bias is significantly reduced when surface mixing is included (see left bottom figure).

Comparison of ‘with waves’ and ‘no waves’ simulations with WOA18 data









Wave mixing effect on MLD and Chl-a concentration