

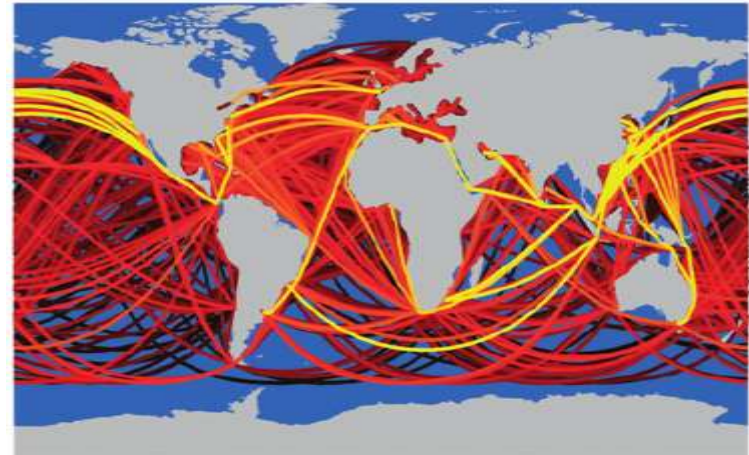
Anthropogenic halocarbons from ballast water treatment

Josefine Maas¹, Susann Tegtmeier¹, Birgit Quack¹,
Arne Biastoch¹

¹GEOMAR Helmholtz Centre for Ocean Research Kiel

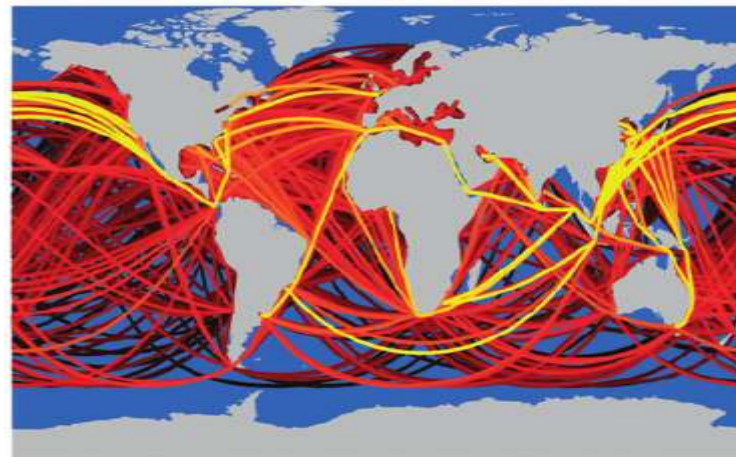


Ballast Water Management



Seebens et al., 2013

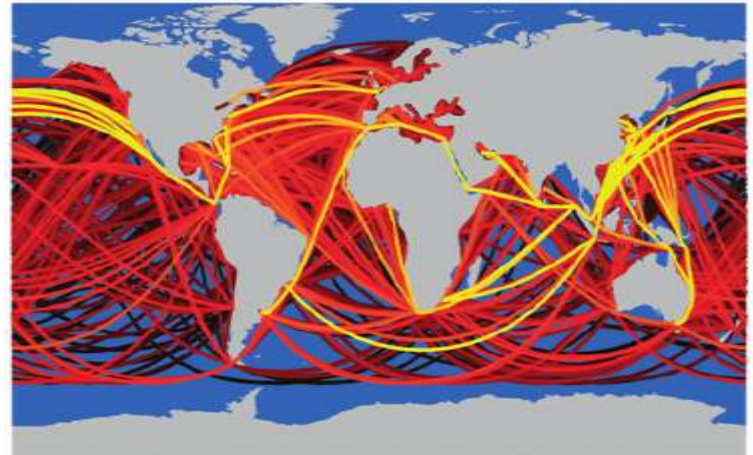
- Industrial shipping as major vector for introduction of non-indigenous species



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Ballast Water Management

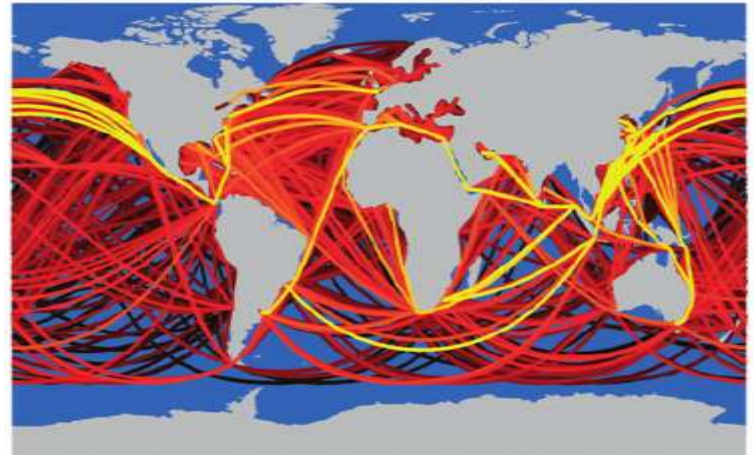
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- IMO Ballast Water (BW) Management Convention (IMO, 2004) in force since Sep. 2017



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Ballast Water Management

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- IMO Ballast Water (BW) Management Convention (IMO, 2004) in force since Sep. 2017
- Estimates of $3-5 \times 10^9$ tons BW discharged annually



Seebens et al., 2013

Halocarbons in Ballast Water

Halocarbons are **disinfection by-products** (DBPs) in ballast water treatment systems (BWTS) (Werschkun et al., 2012)

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- **Bromoform** is main compound
- High concentration in chemical BWTS (chlorination)
- Found in all types of BWTS
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Impacts of Bromoform (CHBr₃):

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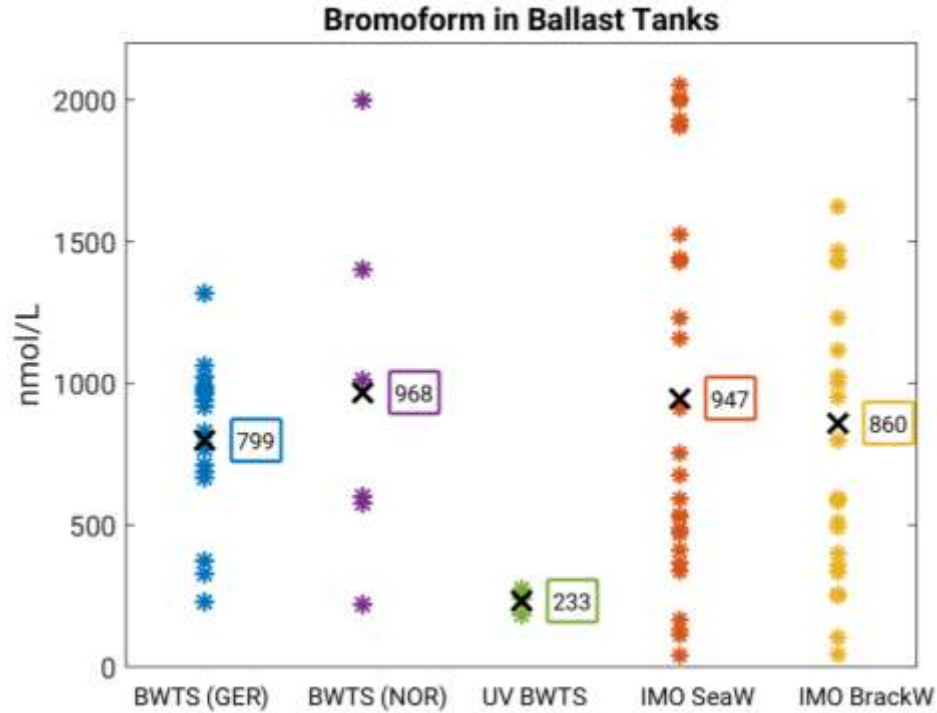
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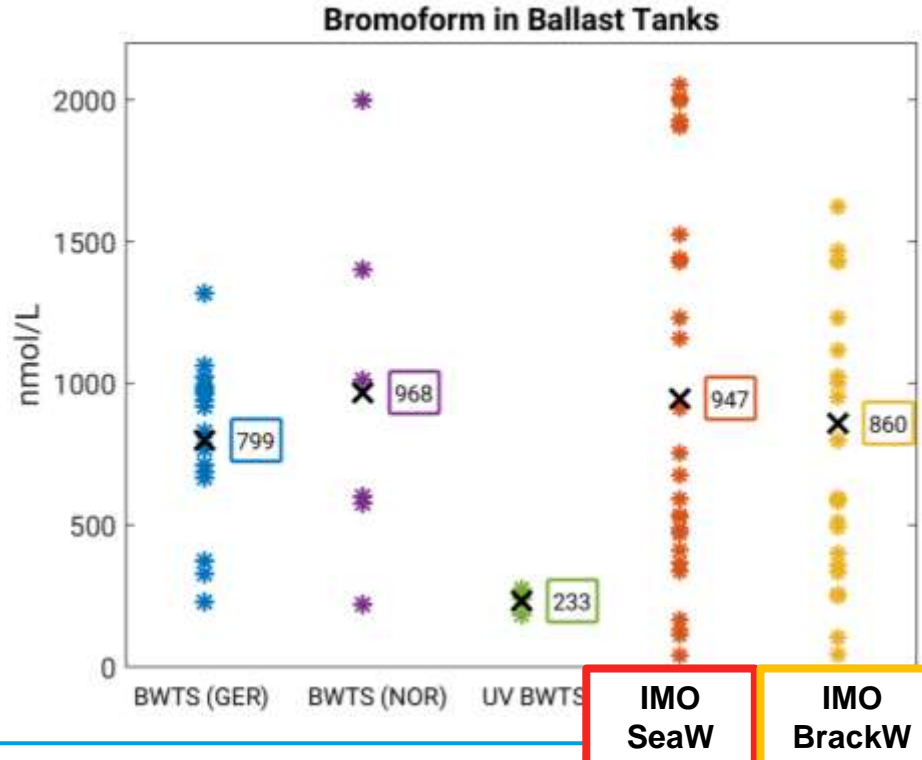
Impacts of **Bromoform (CHBr₃)**:

- High ozone depletion potential
- Change of radiative forcing
- Decline of atmospheric oxidising capacity

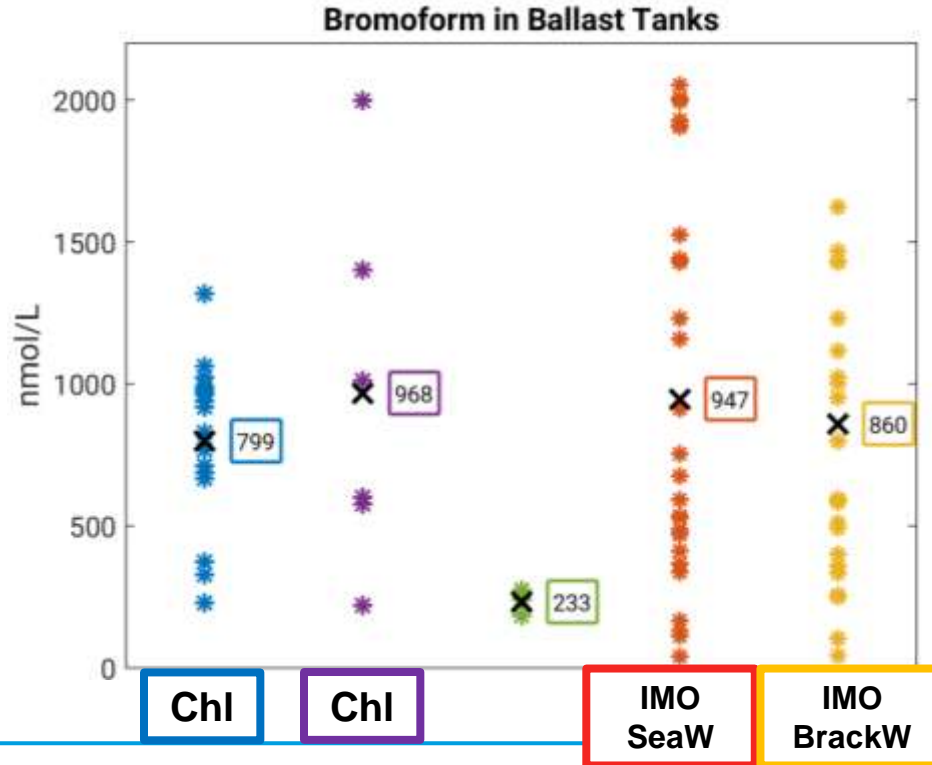
Bromoform in BW



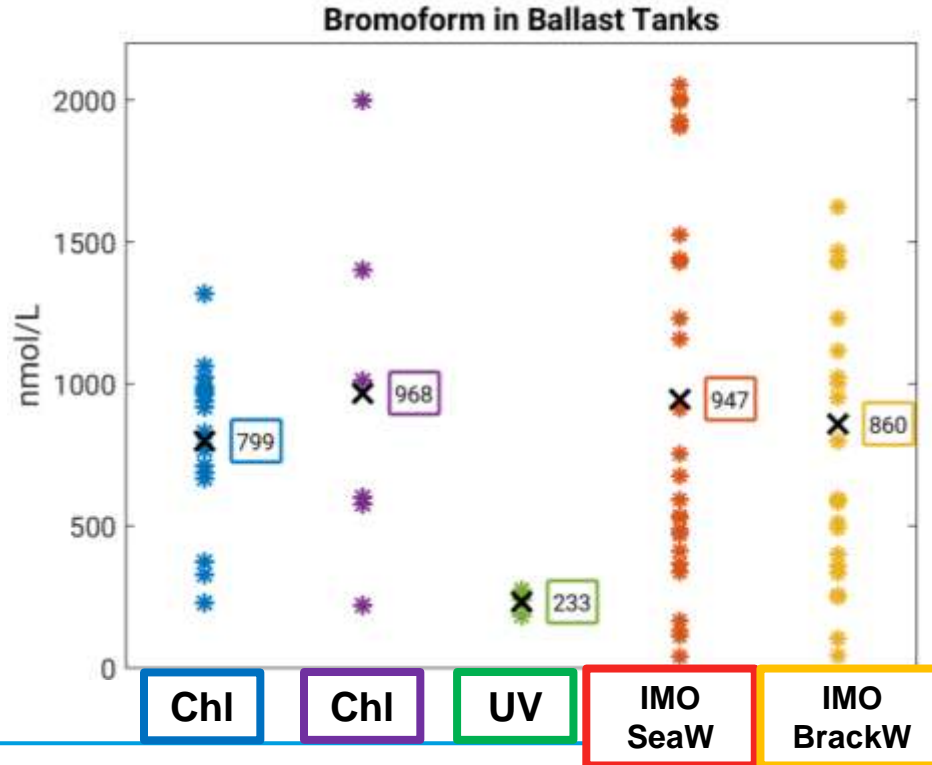
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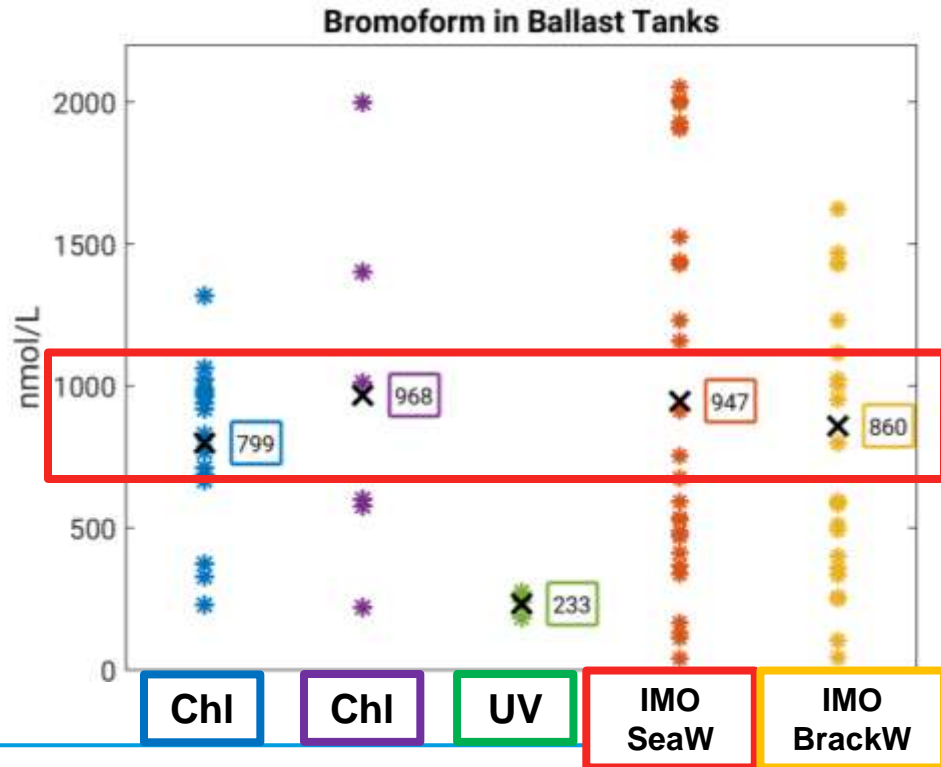
Bromoform in BW



Bromoform in BW



Bromoform in BW



**Chemical Treatment,
e.g. Chlorination,
Ozonation**

BW vs. Ocean Concentration

Natural halocarbons

Chemical BW treatment

Natural halocarbons

Chemical BW treatment

Chlorination
Ozonation



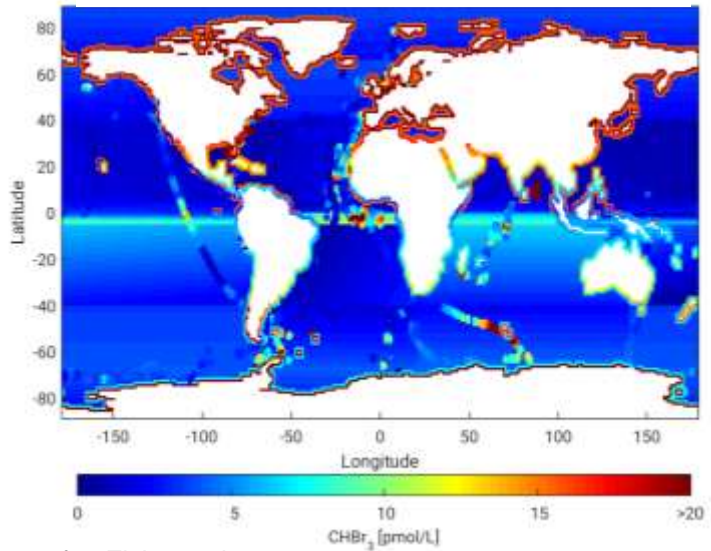
DPBs

**~900 nmol/L
Bromoform**

BW
concentration

BW vs. Ocean Concentration

Natural halocarbons



after Ziska et al., 2013



~40 pmol/L
Bromoform
Shelf water
concentration



Chemical BW treatment

Chlorination
Ozonation

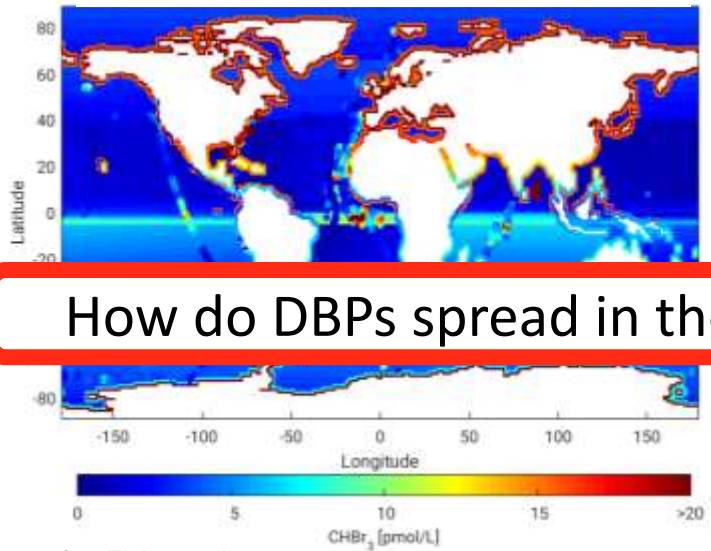


DPBs

~900 nmol/L
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BW vs. Ocean Concentration

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Chemical BW treatment

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How do DBPs spread in the surface ocean after BW discharge?

~40 pmol/L
Bromoform
Shelf water
concentration



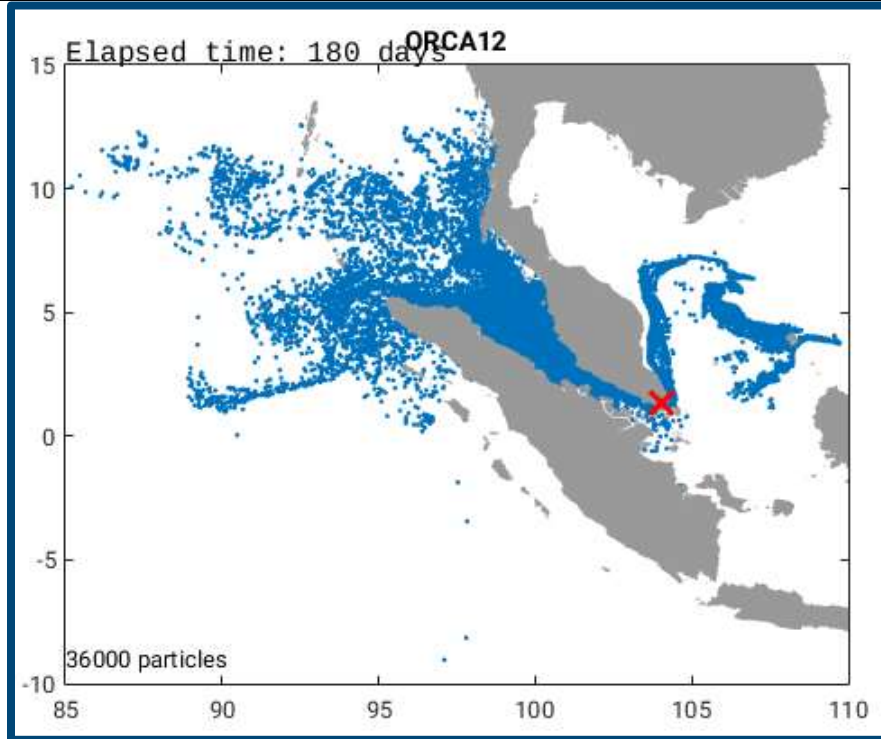
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Simulation of BW Spread with NEMO-ORCA12



- NEMO-ORCA12 high-resolution (1/12°) velocity field
- Continuous input of particles at each time step
- One harbour/region as release area -> Singapore

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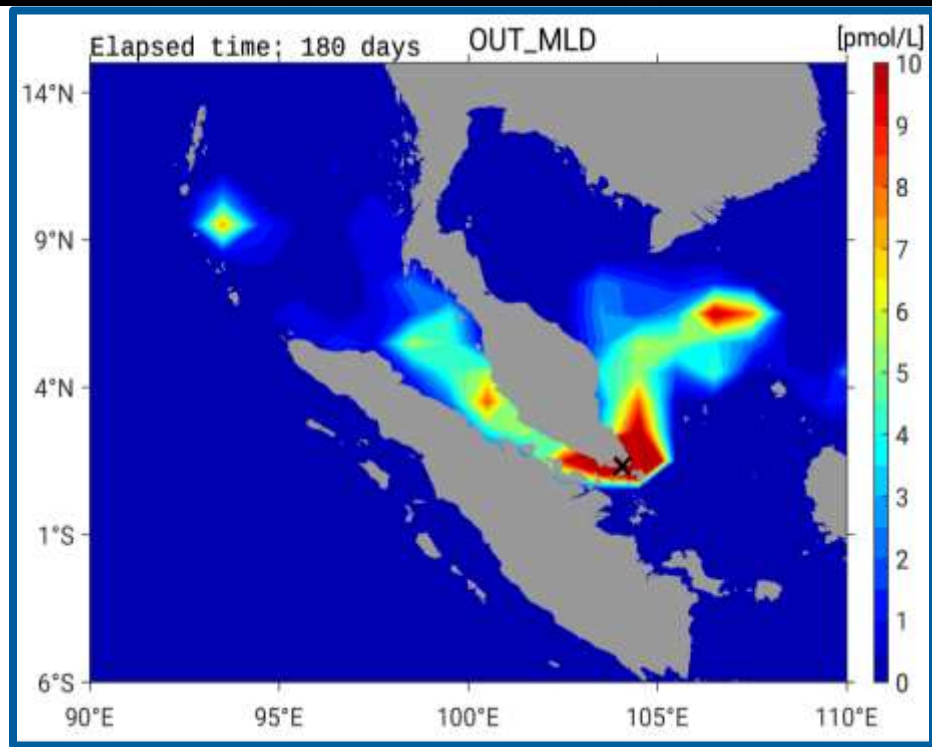


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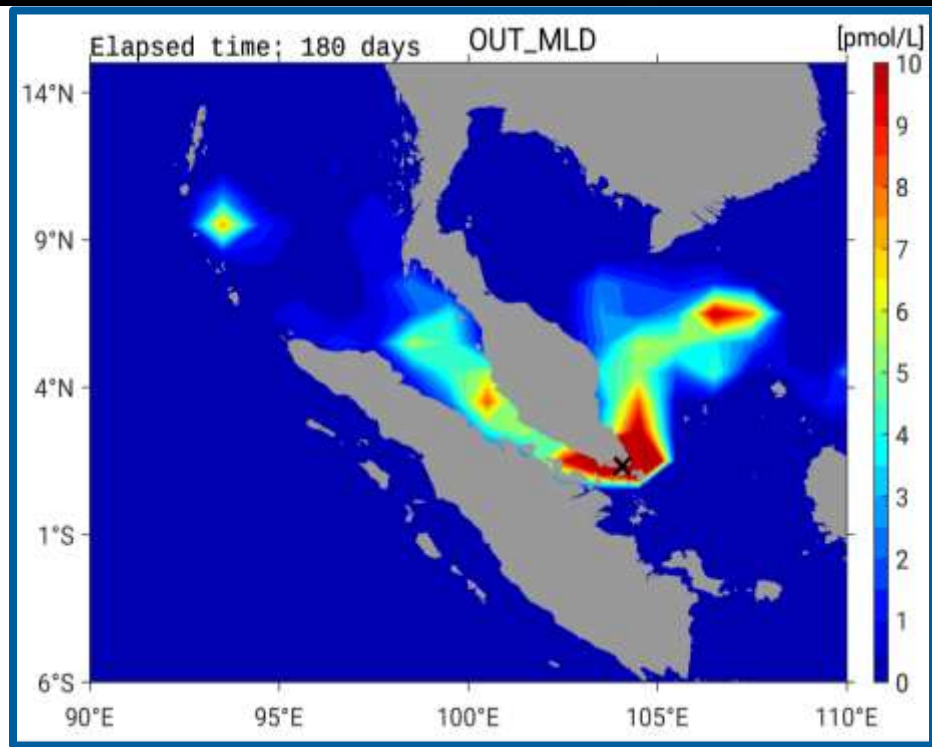
- Surface particle density
-> Bromoform concentration [pmol/L]

Singapore BW Experiment – Concentration 0.5yr



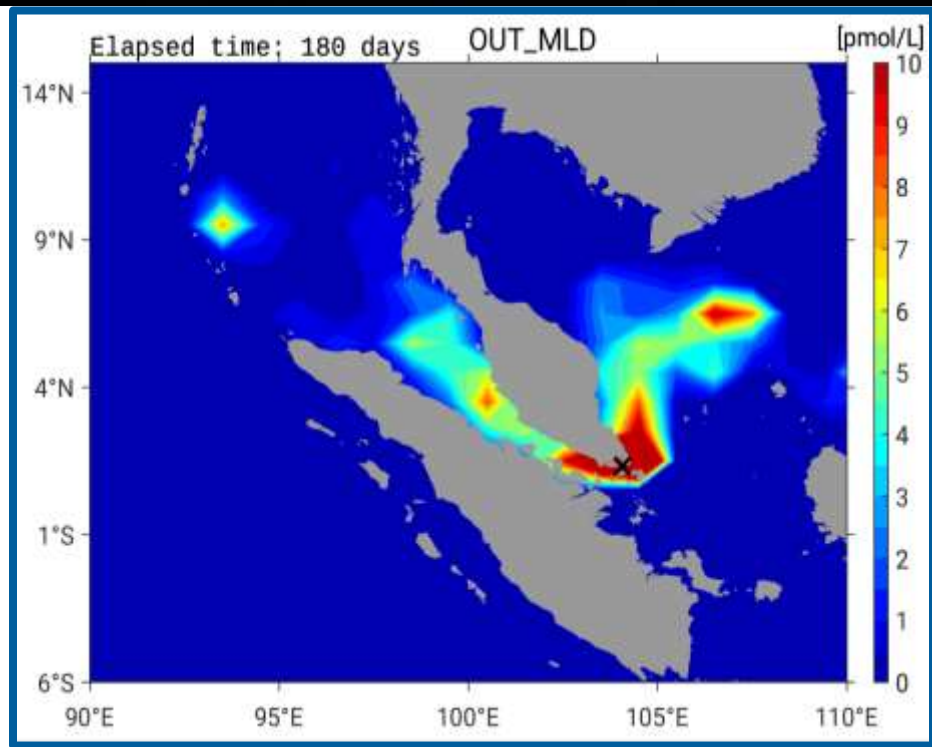
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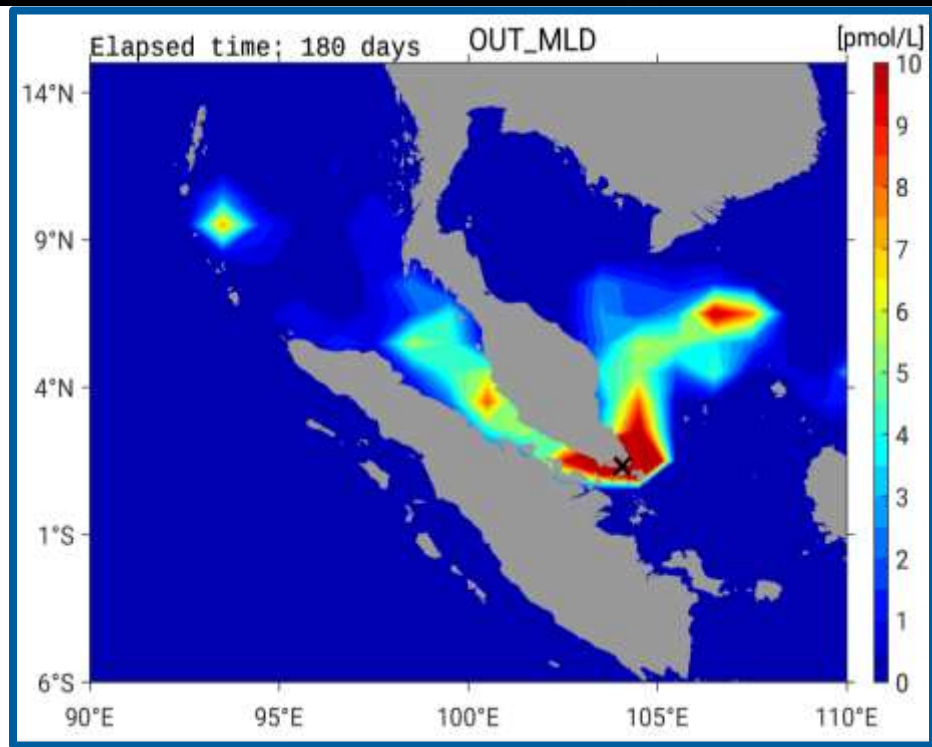


- Surface particle density
- > Bromoform concentration [pmol/L]
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- Surface concentrations from one harbour reach up to 30 pmol/L



Singapore BW Experiment – Concentration 0.5yr

GEOMAR



- Surface particle density
- > Bromoform concentration [pmol/L]
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~40 pmol/L
Bromoform

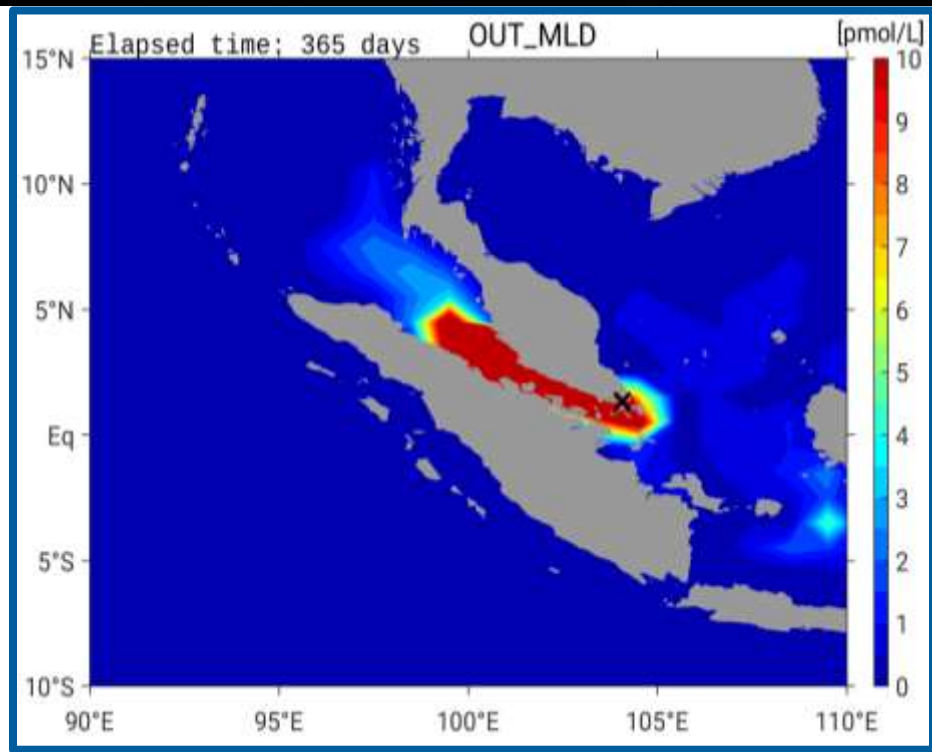


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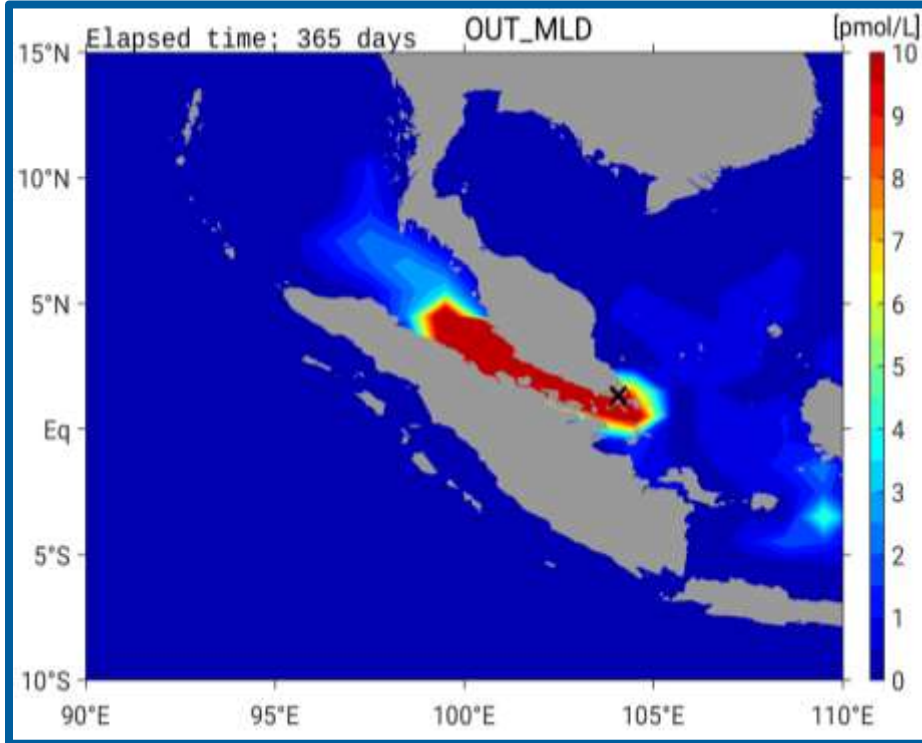
Shelf water concentration

Singapore BW concentration

Singapore BW experiment – Concentration 1yr



Singapore BW Experiment – Concentration 1yr

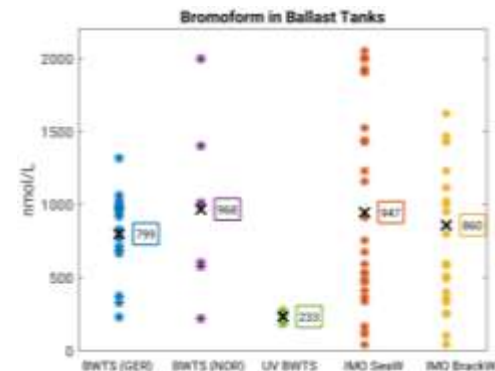


- Bromoform from BW concentrates in Strait of Malakka

Summary

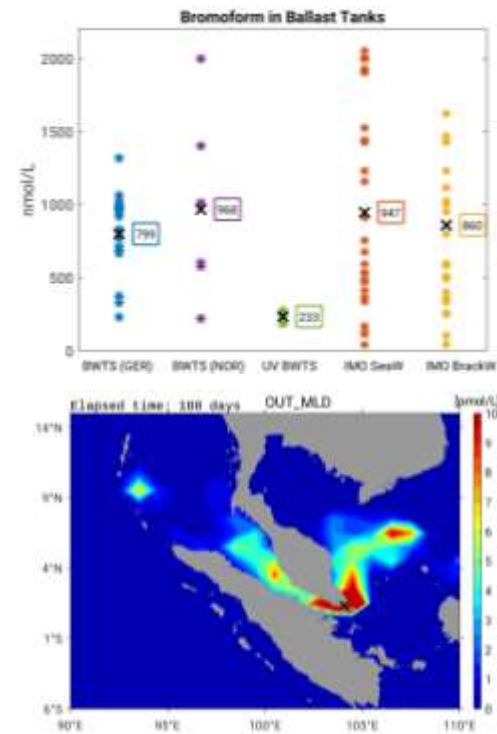
Summary

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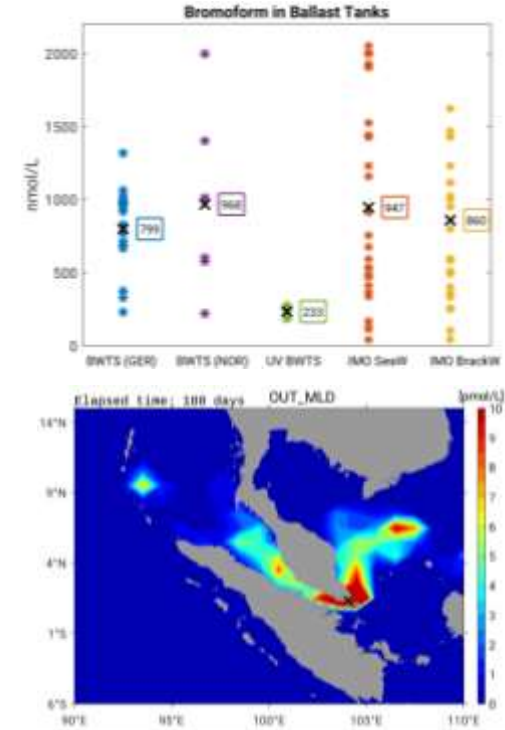
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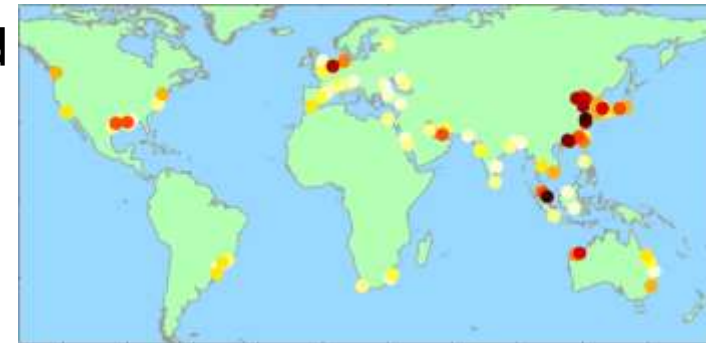
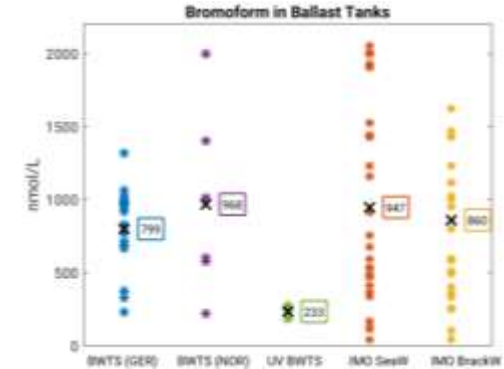
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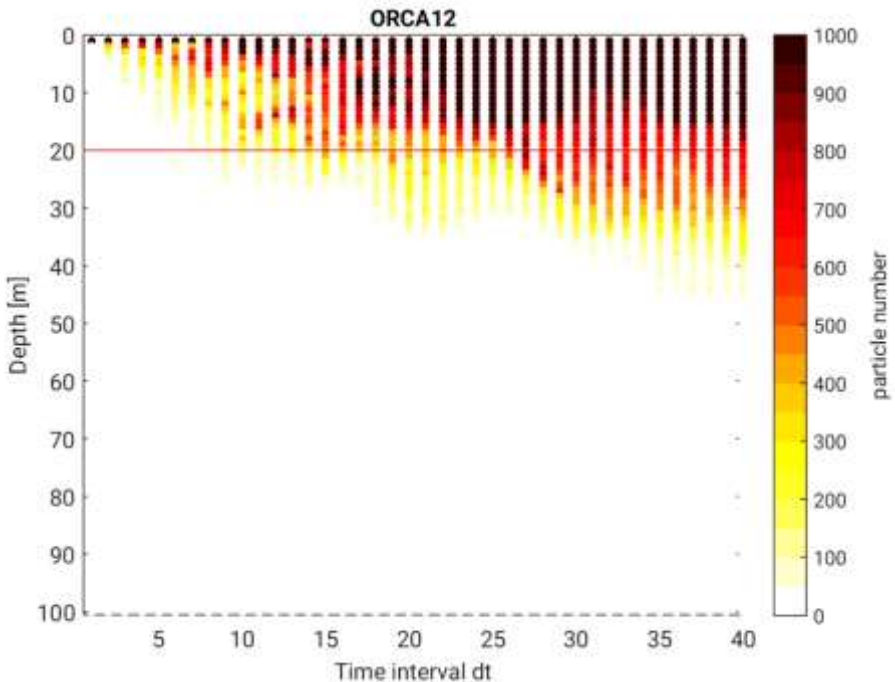
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- Singapore harbour only, causes up to 30 pmol/L bromoform at surface (same magnitude as natural)
- DBP spread is dependent on regional and coastal processes
- Significant contribution to global anthropogenic halocarbons expected



Thank you for your attention!

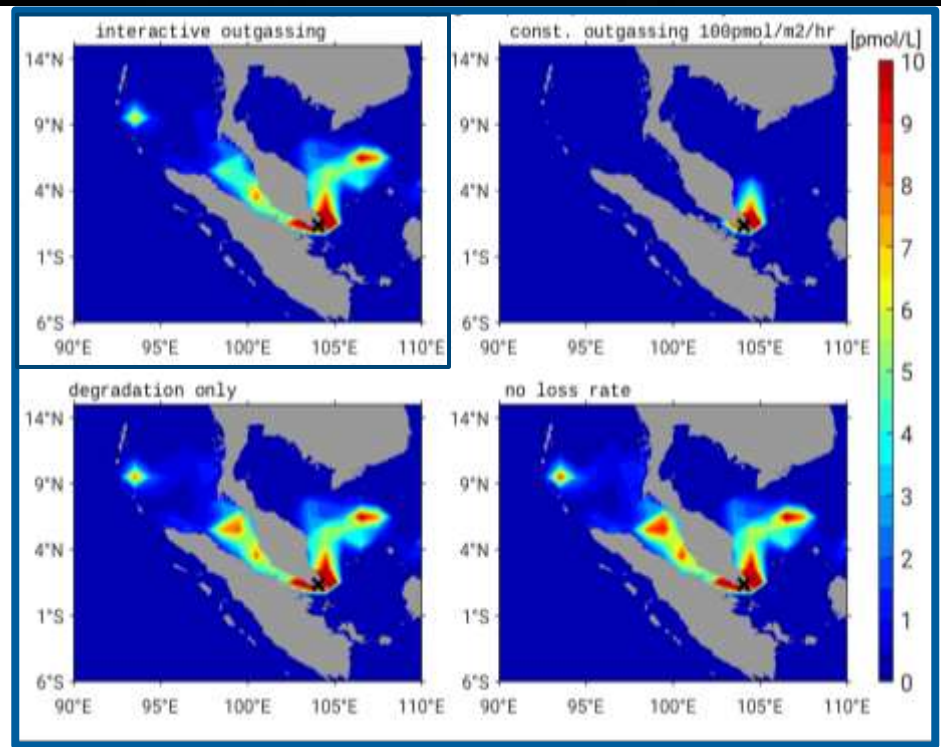
ORCA12: Depth Evolvment



Harbours SE Asia



Singapore BW experiment – Scenarios



- Sea-Air flux from mixed layer
 - Const. flux rate
 - Degradation
-
- Sea-air flux stronger than degradation
 - Less flux in MLD than const. flux rate