Numerical dye tracer experiments in Bedford Basin in support of Ocean Alkalinity Enhancement research

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Motivation

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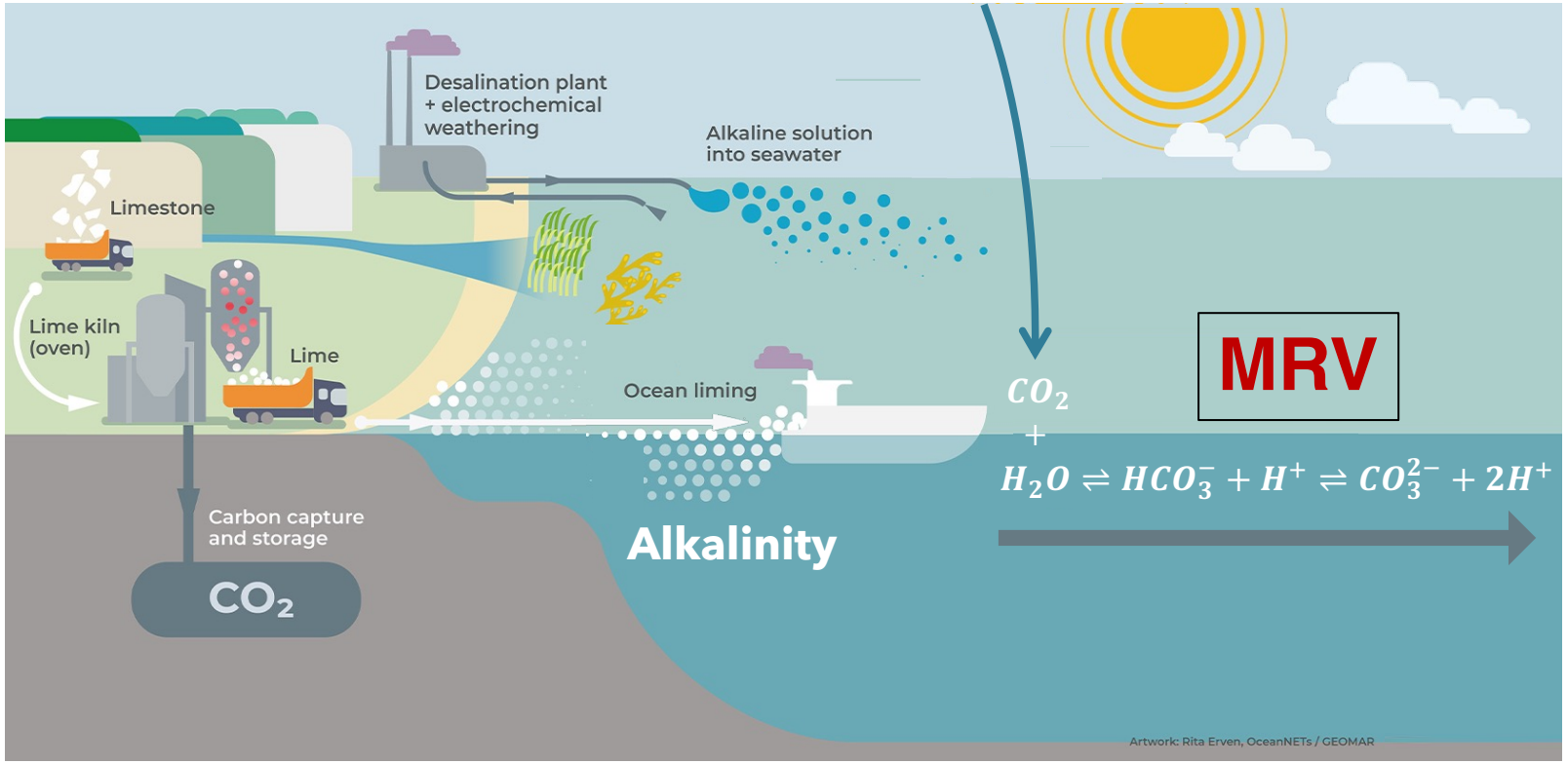


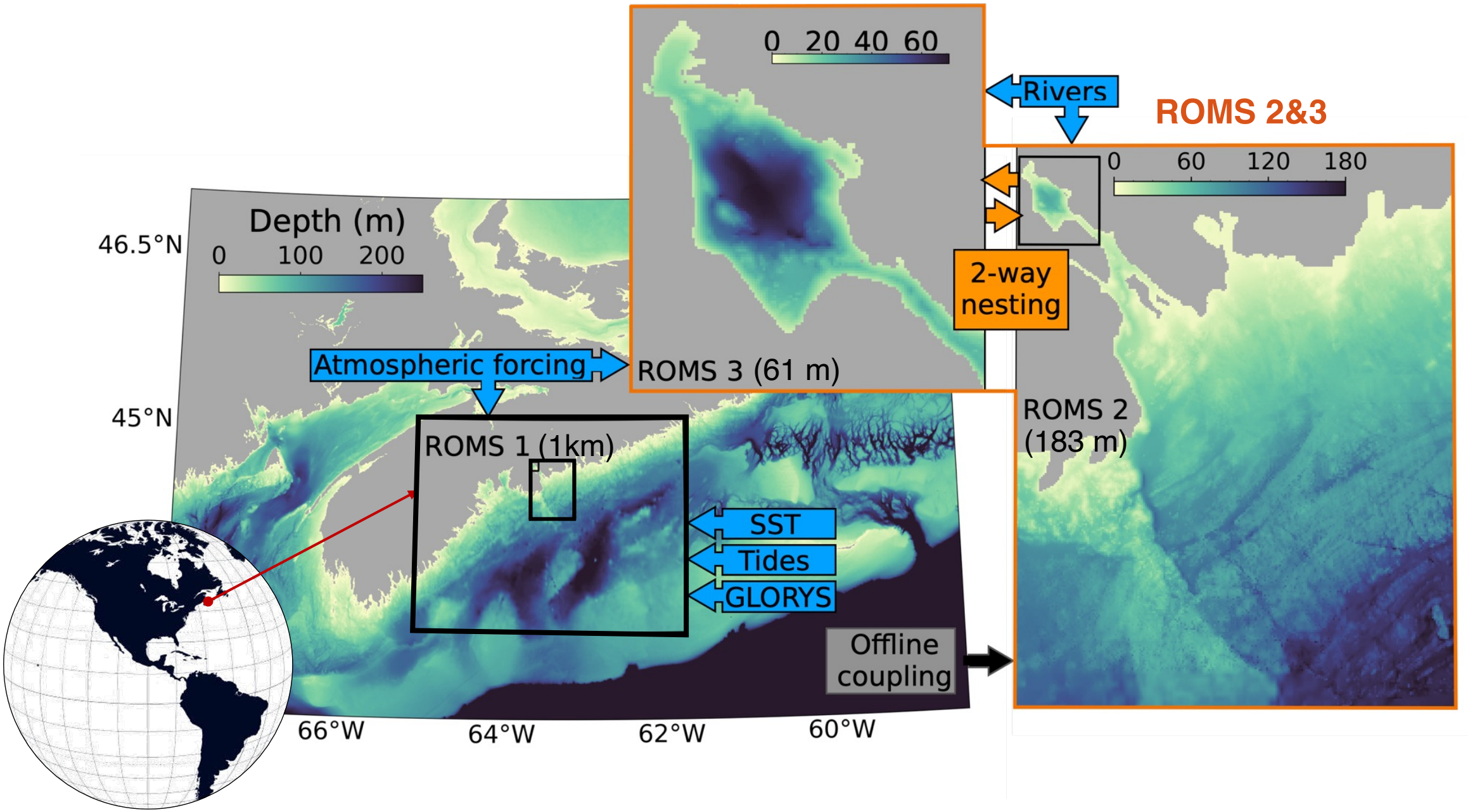
Adapted from https://www.geomar.de/en/discover/ocean-for-climate-protection/carbon-uptake-in-the-ocean/ocean-alkalinization

Motivation

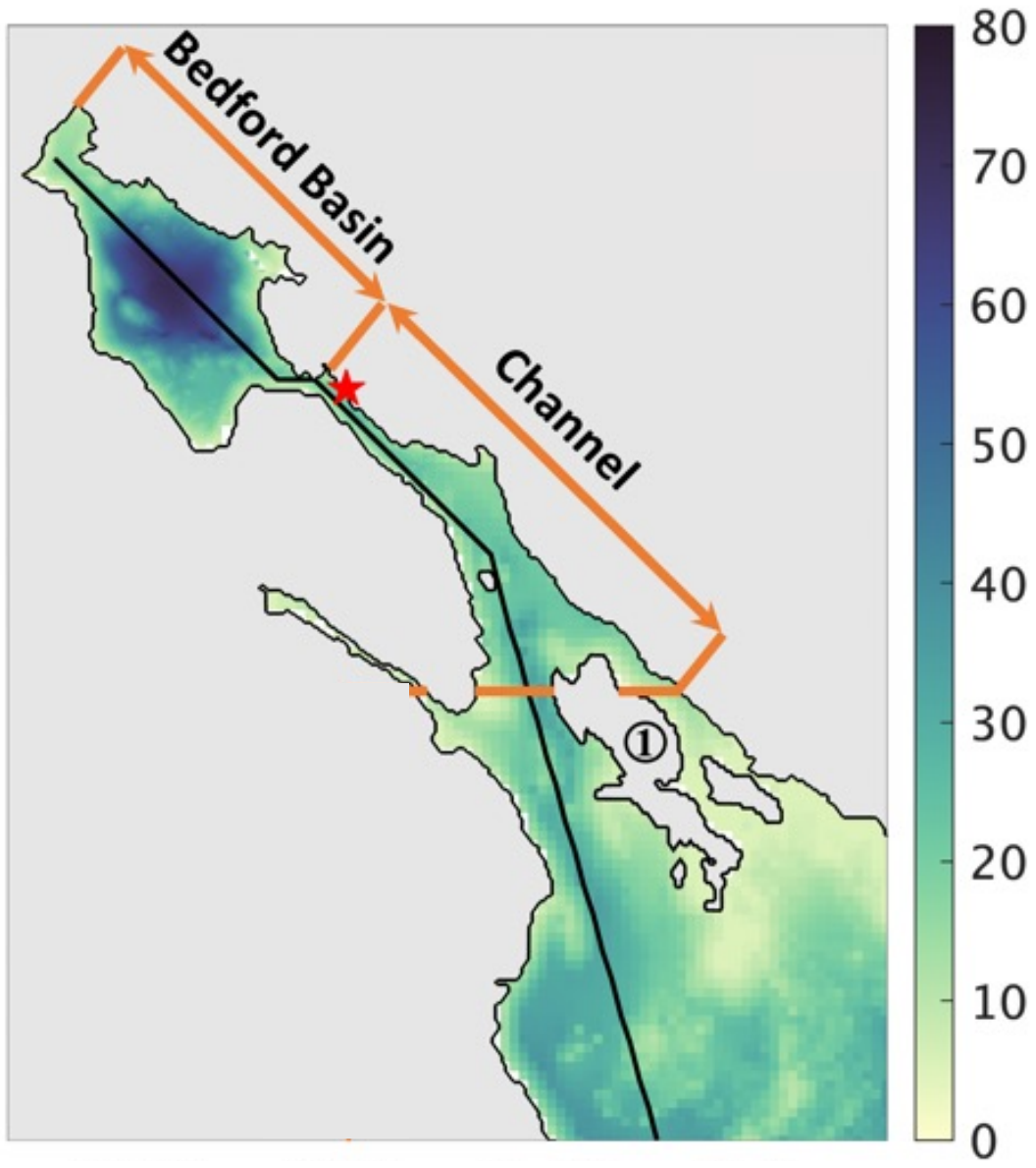
- CDR is necessary to achieve **net-zero emission** and stabilize the **global warming within 1.5 ^{O}C**
- OAE is one of marine-based CDR approaches
- OAE signals, e.g., increased TA, pH, air-sea flux of CO_2, are quickly diluted below the detectable levels

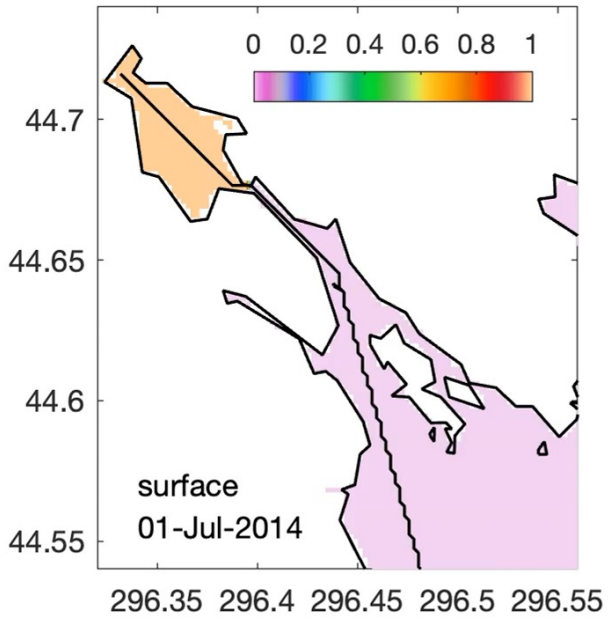
- **Challenge for observing OAE signals and MRV**

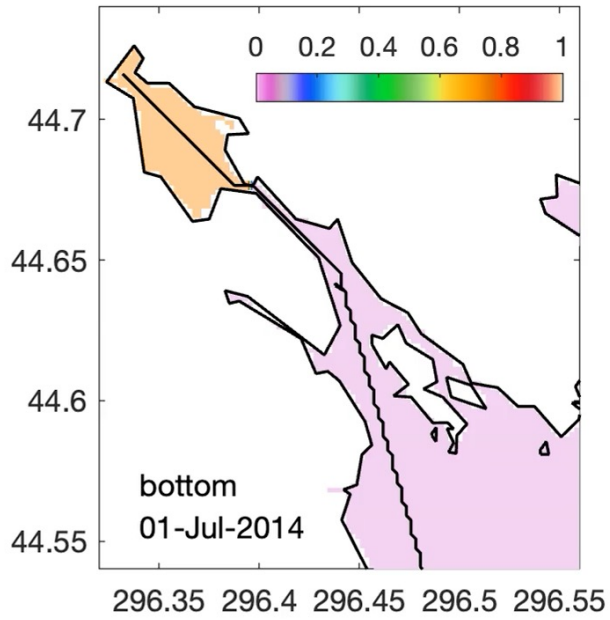
Model description

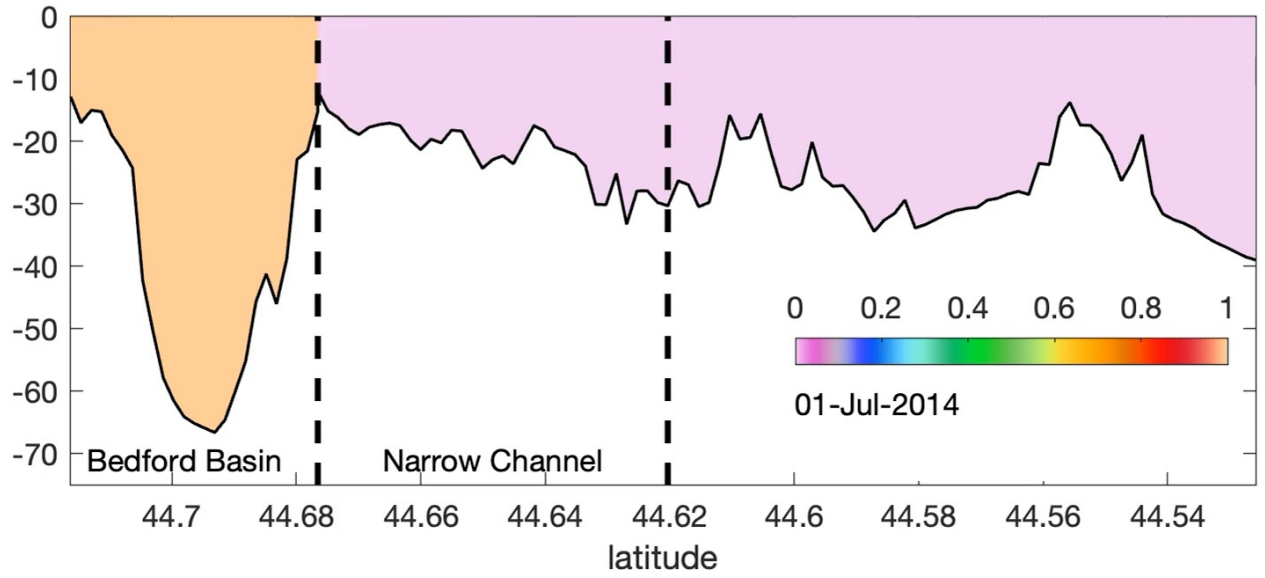


Mean residence time

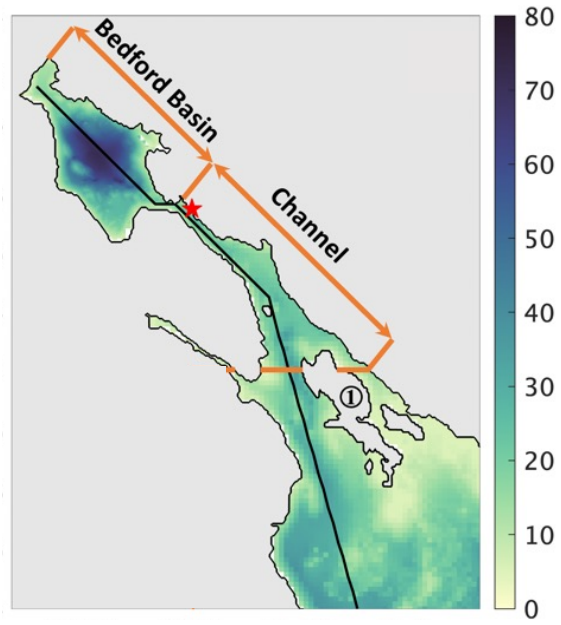




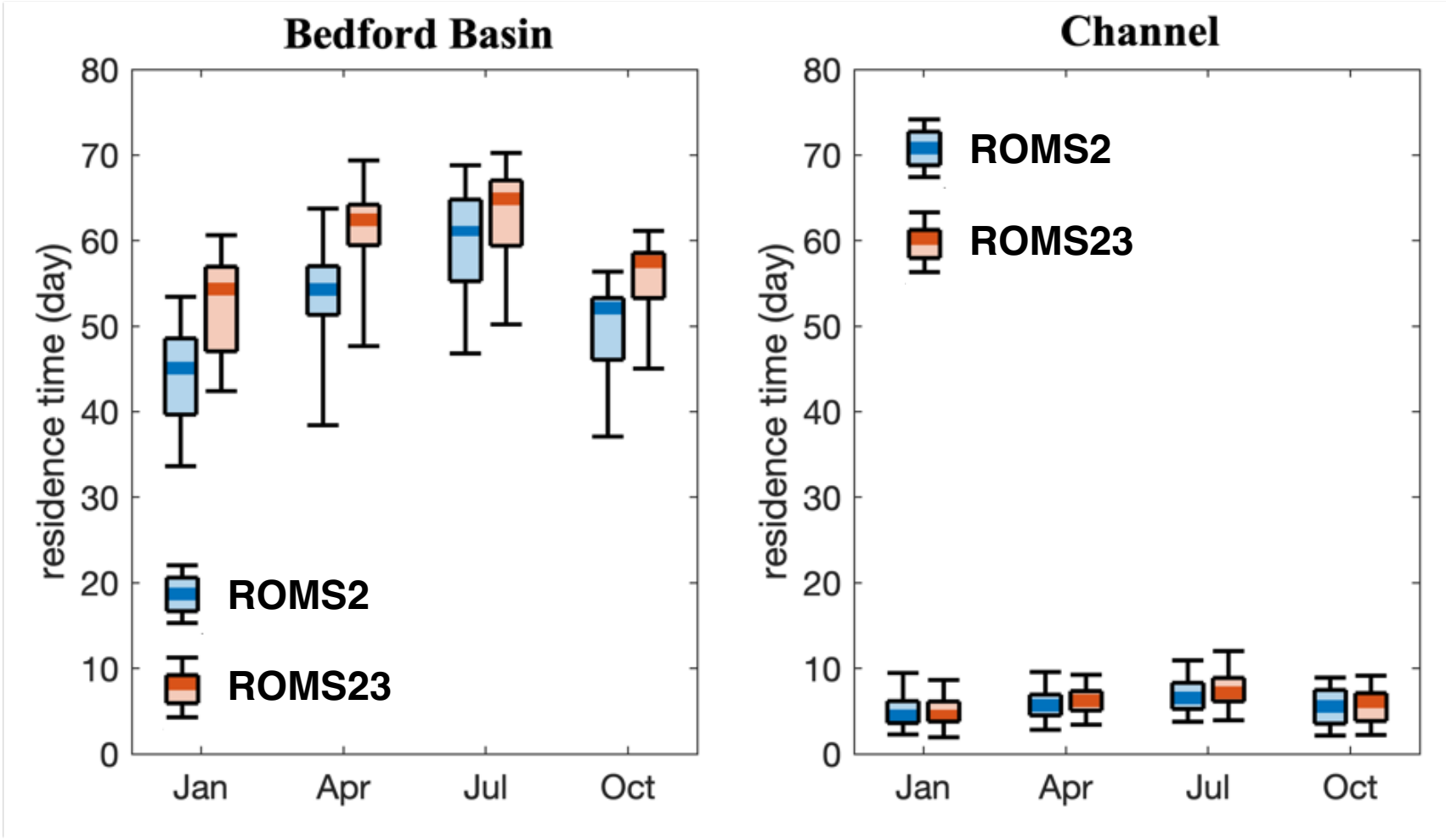




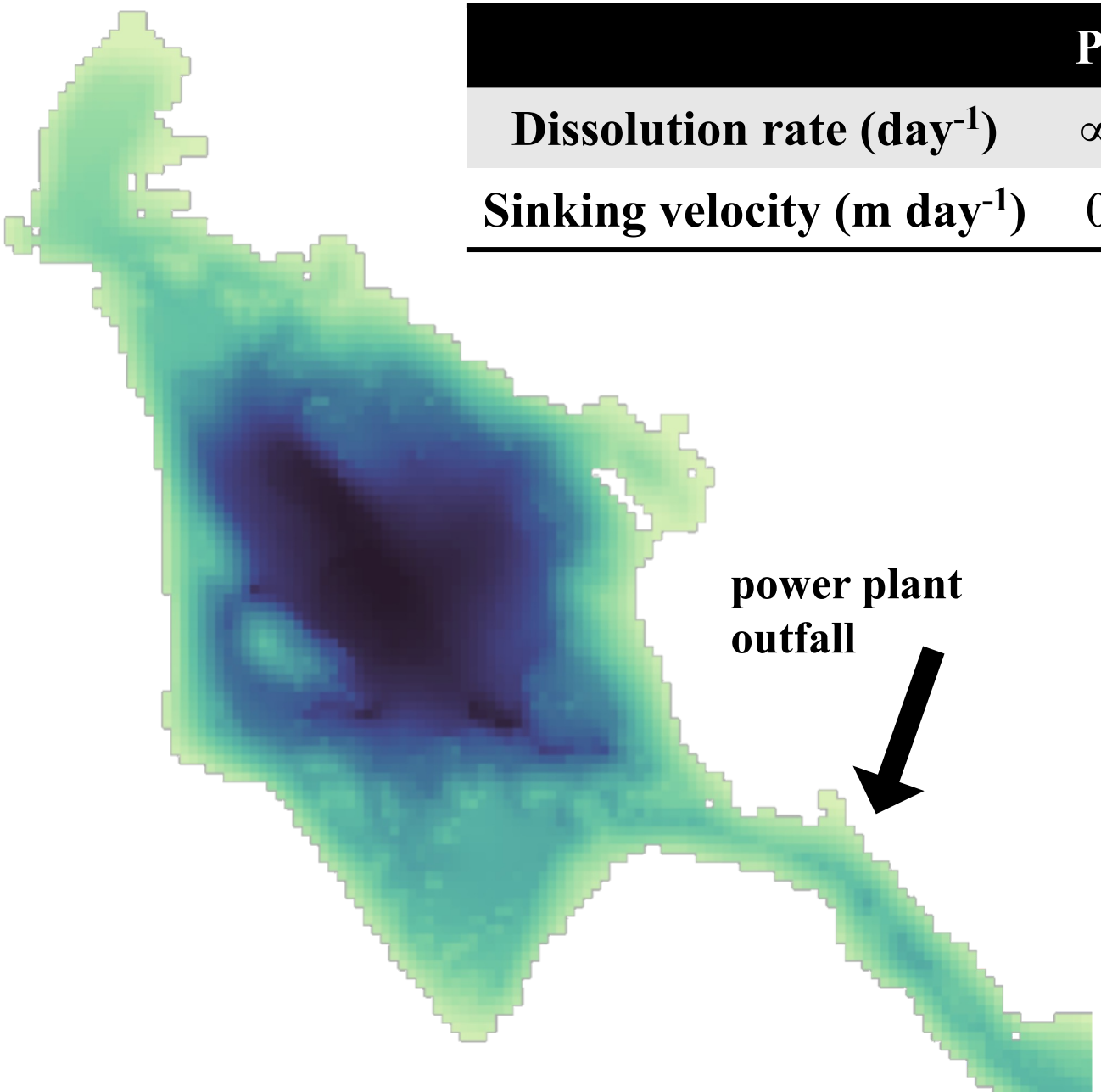
Mean residence time



Seasonal climatology of the MRT over 20 years (2003-2022)



OAE experiments



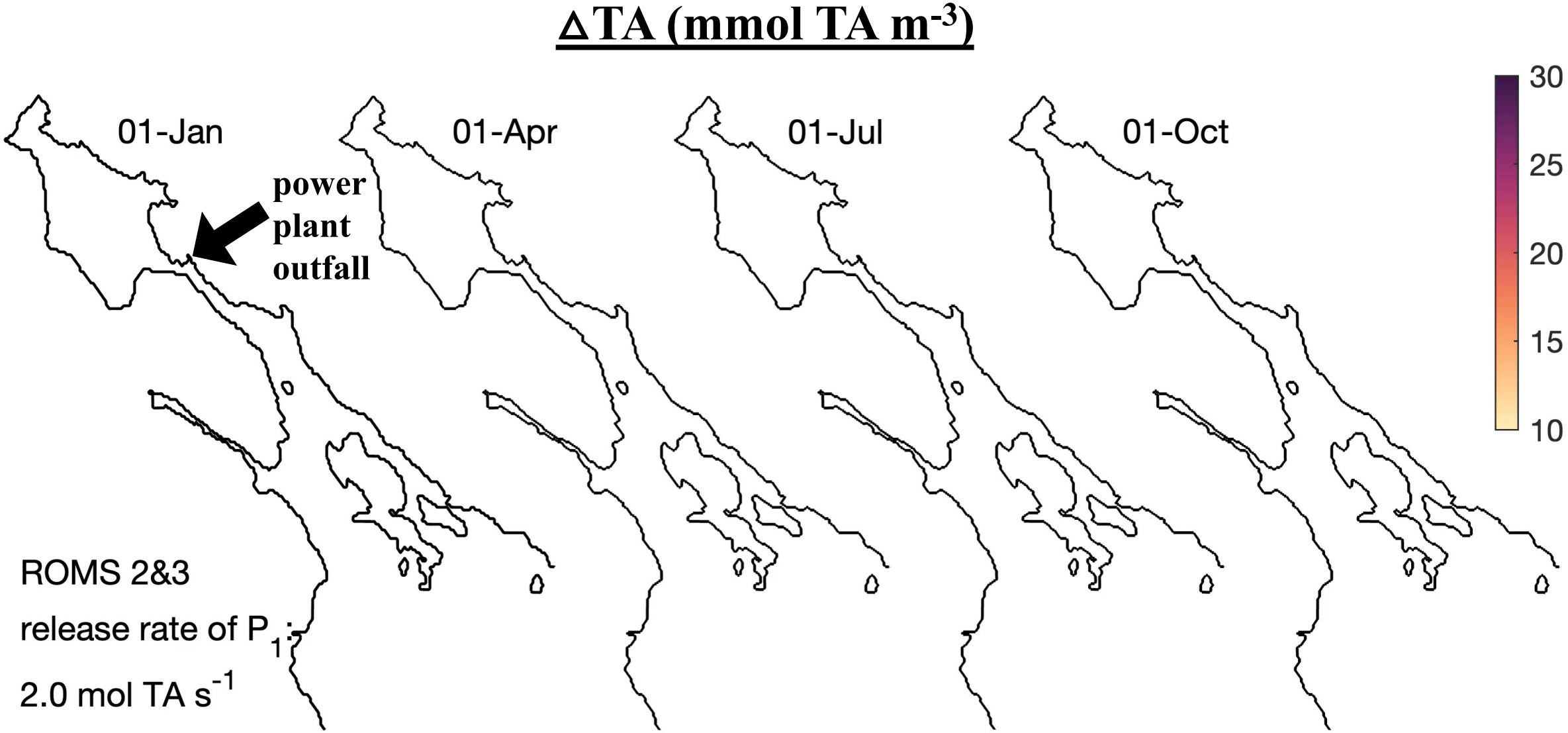
	P_1	P_2	P_{3_1}	P_{3_2}	P_{3_3}	P_{3_4}	P_{4_1}	P_{4_2}	P_{4_3}	P_{4_4}
Dissolution rate (day^{-1})	∞	50	5	5	5	5	0.5	0.5	0.5	0.5
Sinking velocity ($m\ day^{-1}$)	0	0	0	2	5	10	0	2	5	10

Dissolution model
(no biogeochemical cycle/carbon chemistry)

Alkaline minerals:
$$\frac{\partial P}{\partial t} = S - k \cdot P - w \cdot \frac{\partial P}{\partial z}$$

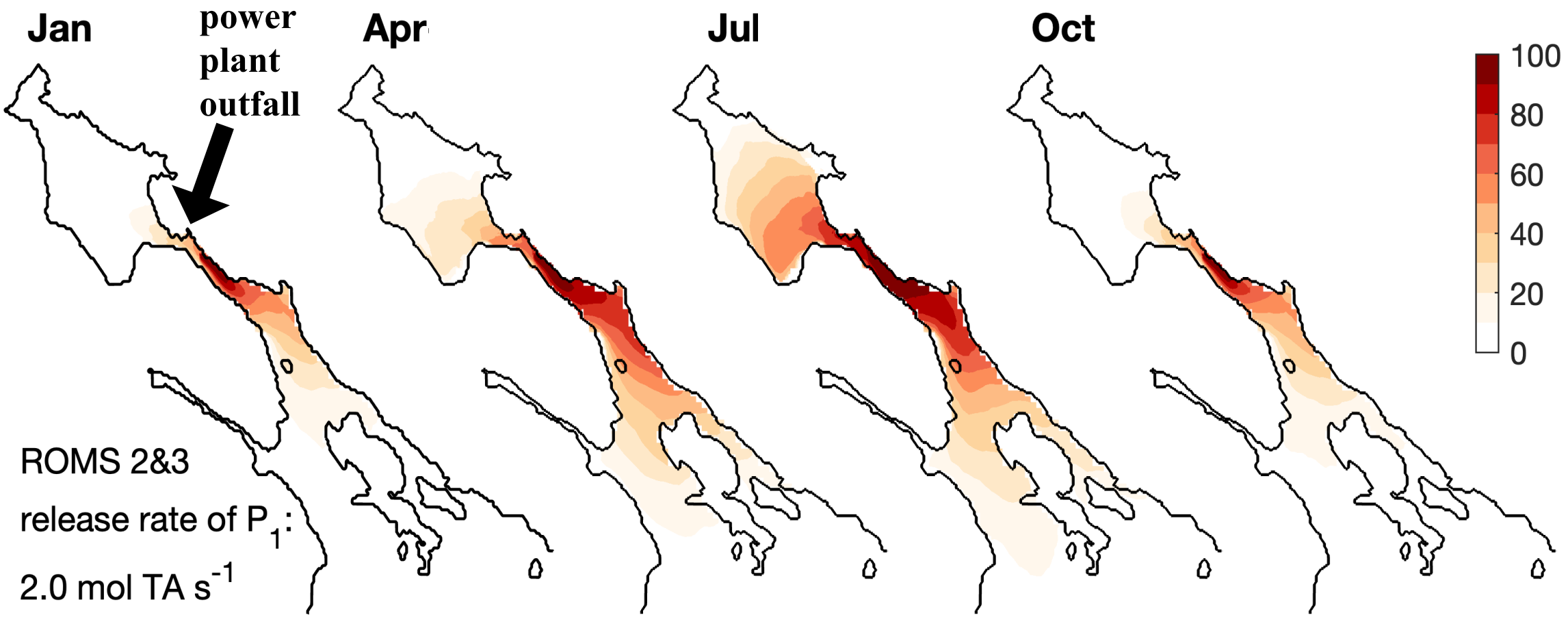
Increased alkalinity:
$$\frac{\partial \Delta TA}{\partial t} = k \cdot P$$

Impact of different seasons



Impact of different seasons

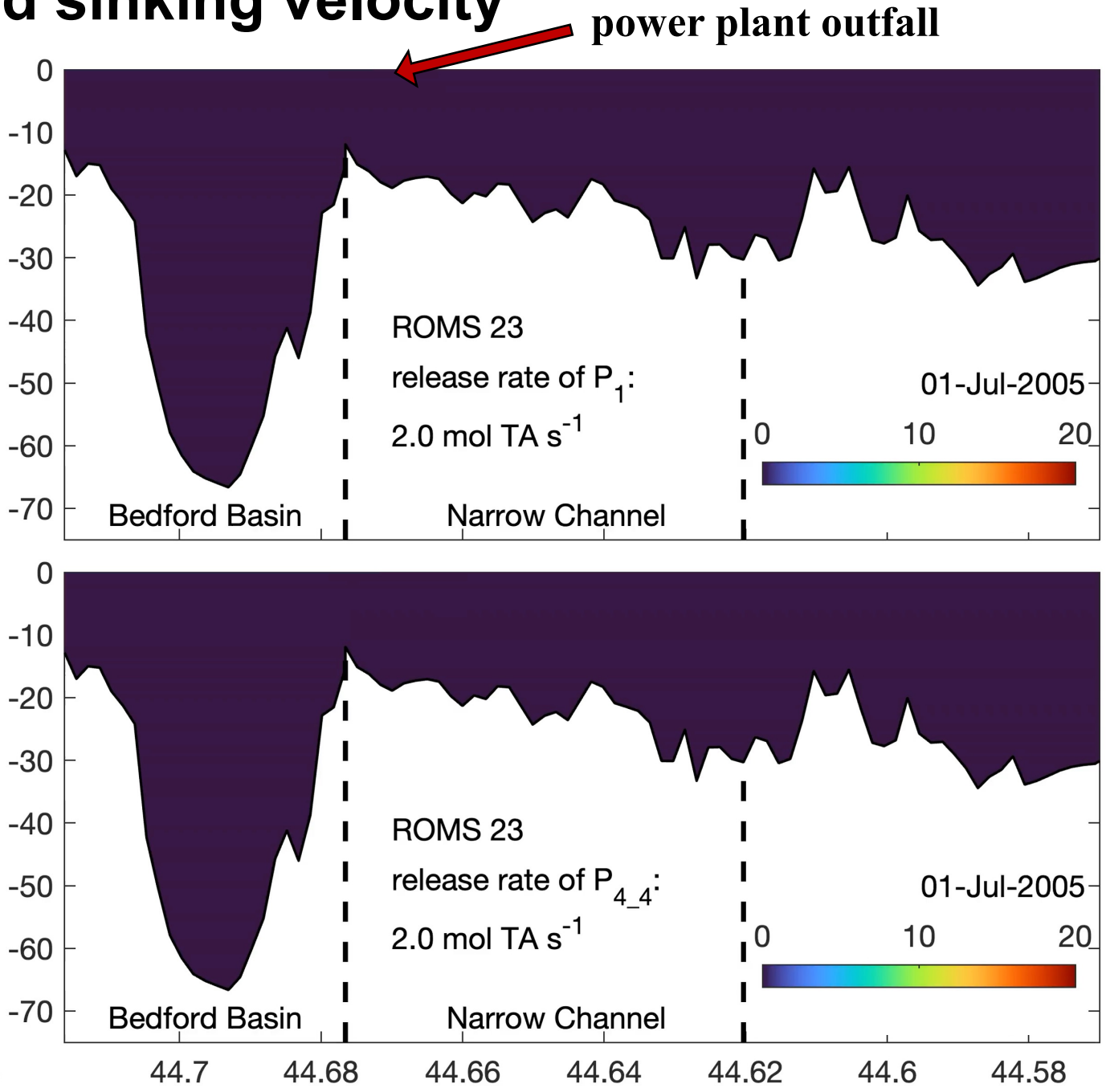
Detectable probability (unit: %)



Impact of dissolution rate and sinking velocity

Add alkalinity directly

Add alkaline particles
Sinking rate: 10 m day^{-1}
Dissolution: 0.5 day^{-1}



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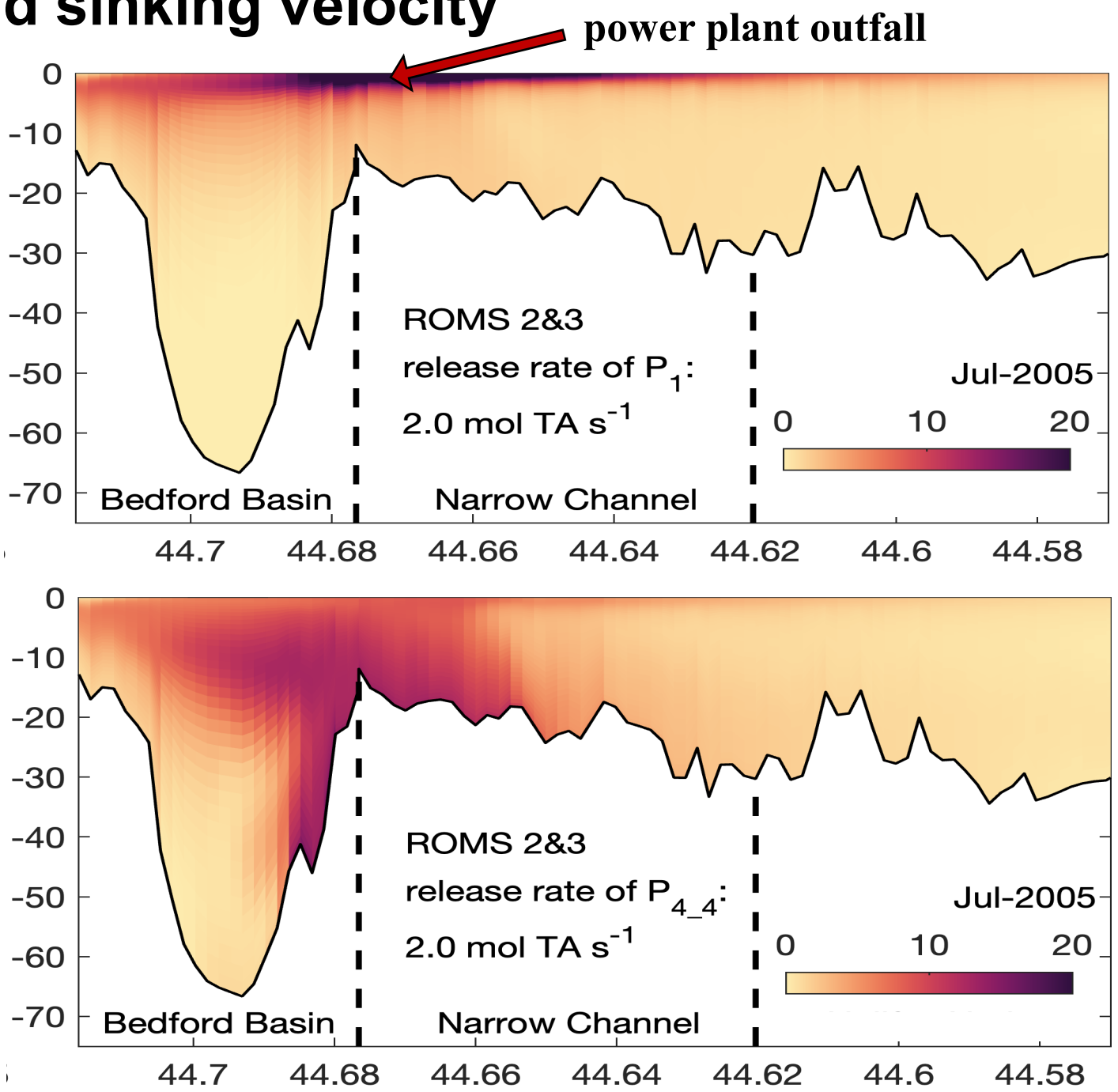

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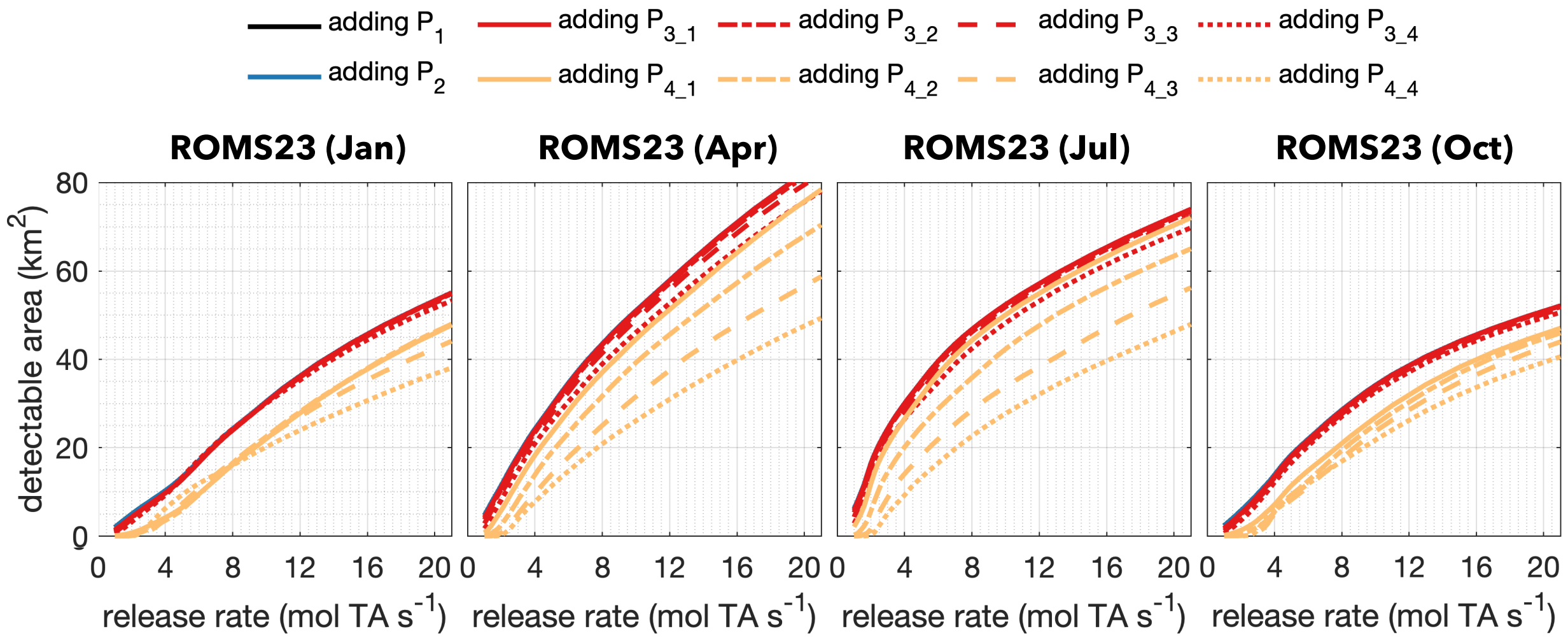

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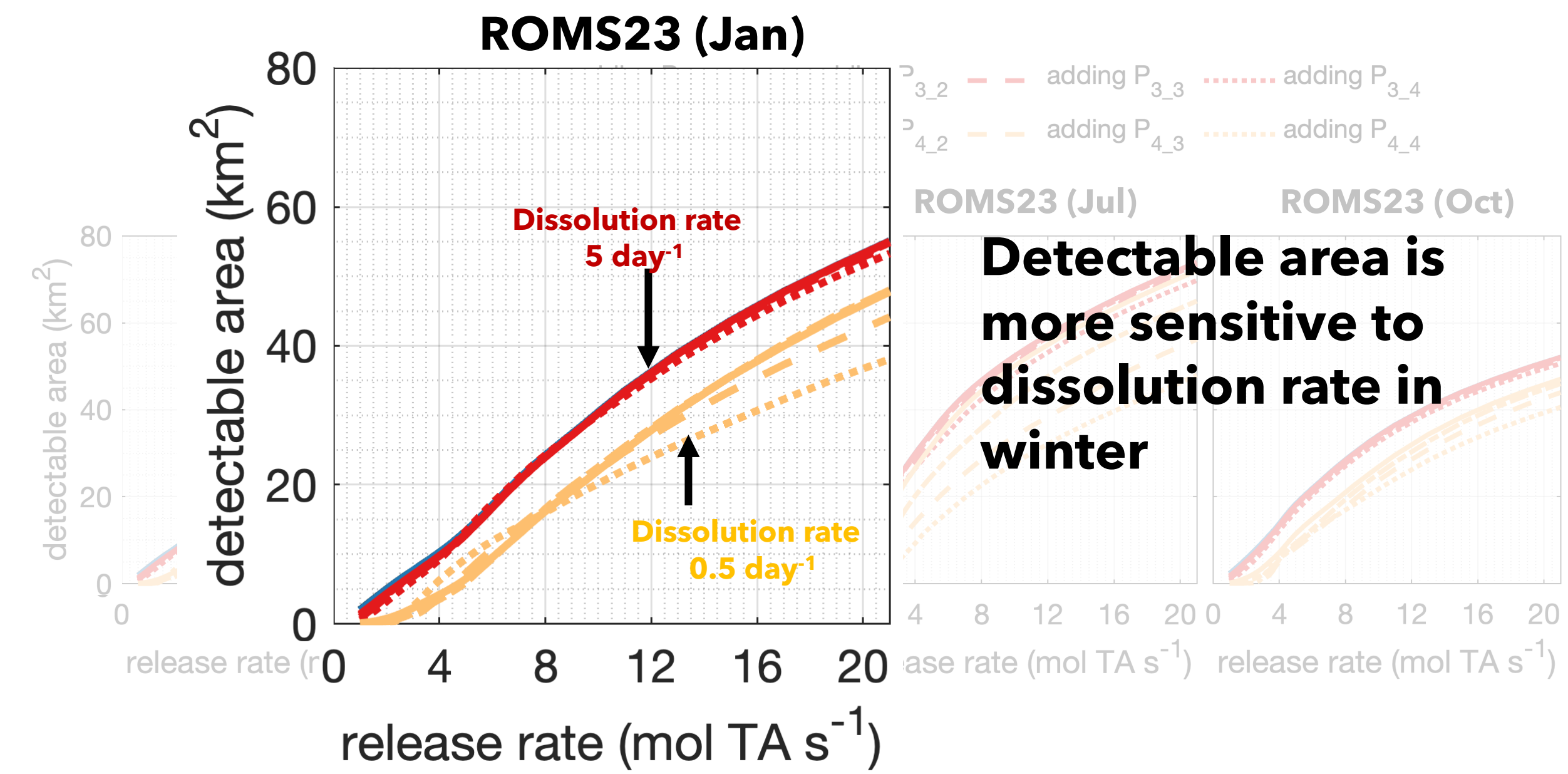
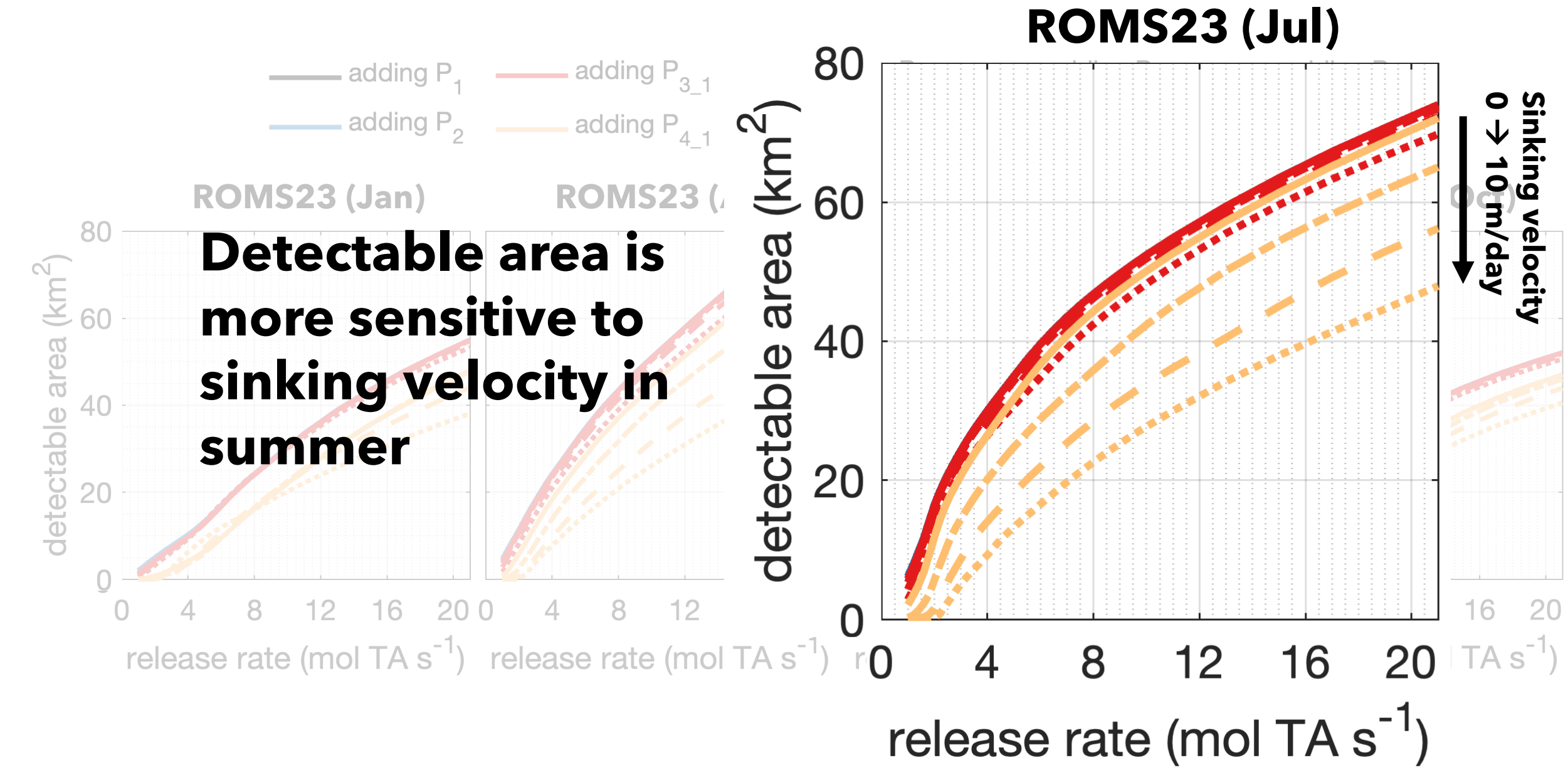
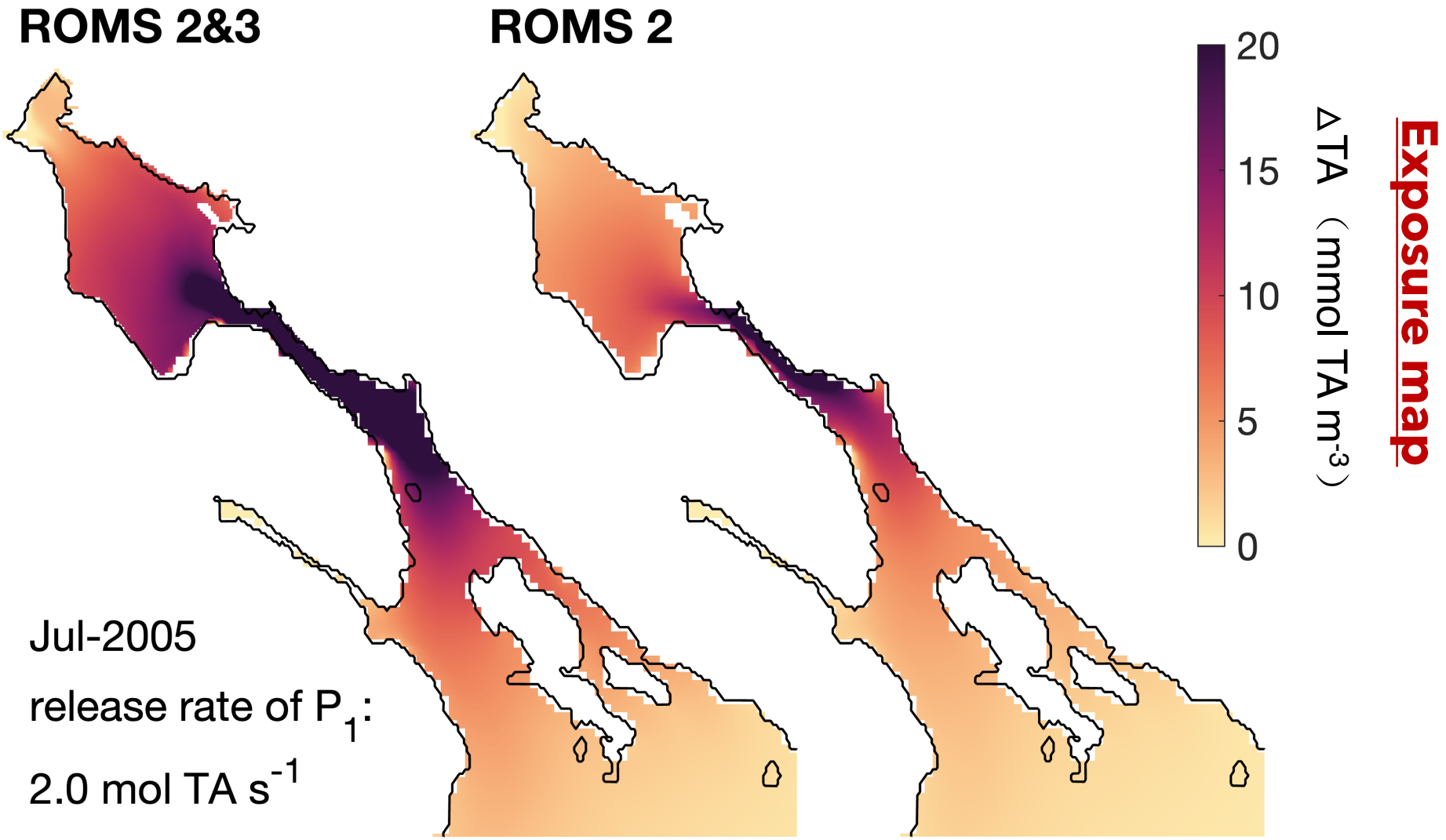


Impact of dissolution rate and sinking velocity



Impact of model resolution



Summary

- The likelihood of detecting OAE signals is higher in July and April because of the longer residence time
- The measurability of OAE signals is sensitive to dissolution rate in winter and to sinking velocity in summer.
- When compared to **ROMS23**, **ROMS2** underestimates the measurability because it overestimates the vertical mixing

Thank you!

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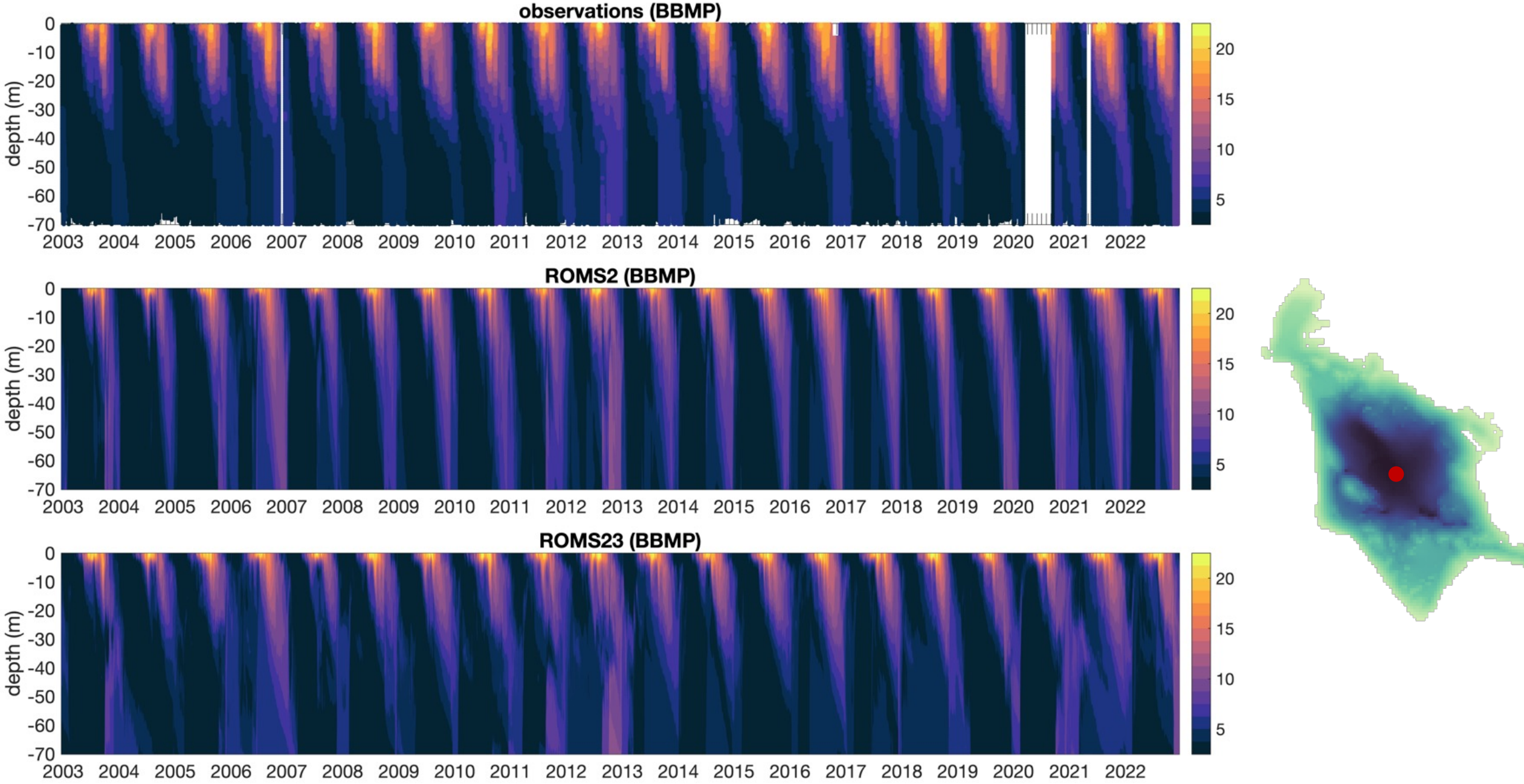
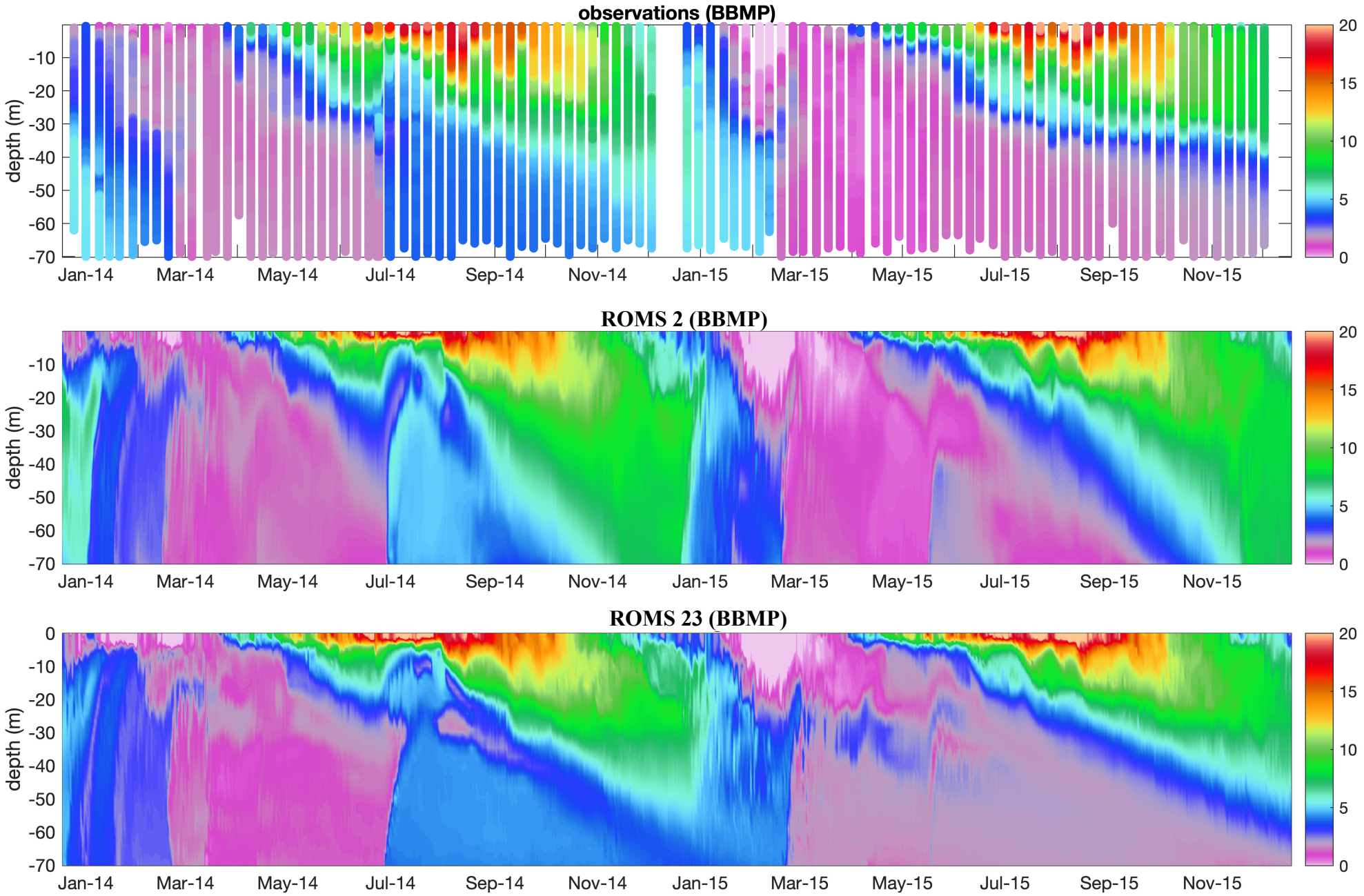
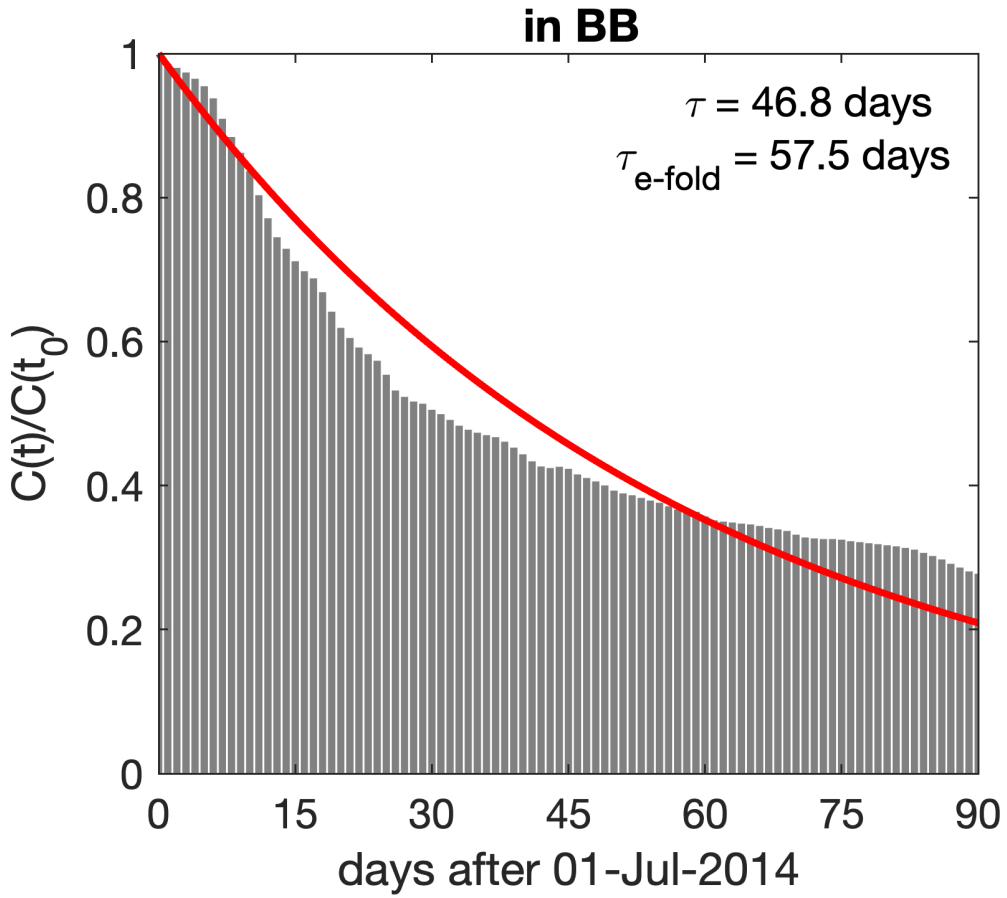
ICONIQ | Impact

Carbon to Sea Initiative

Supplementary slides

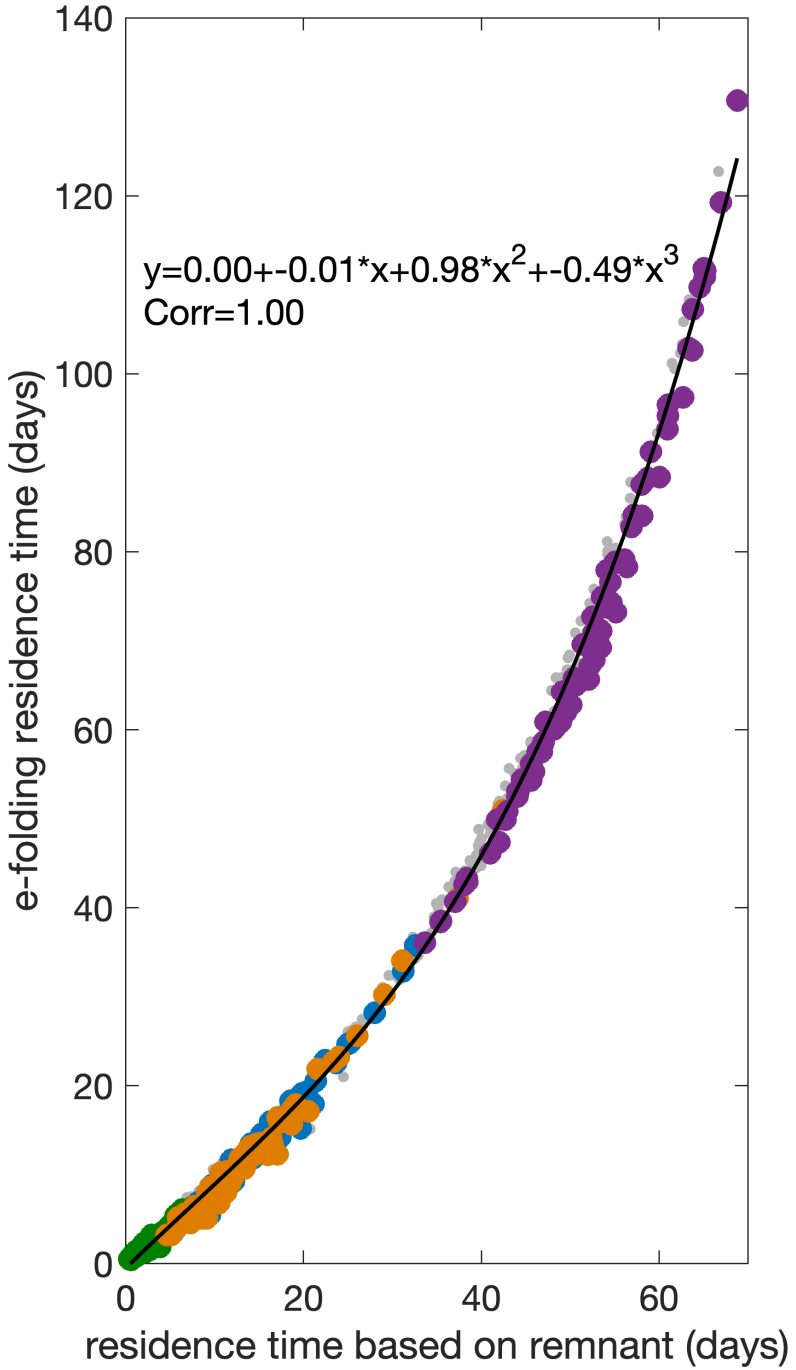

observations (BBMP)
ROMS2 (BBMP)
ROMS23 (BBMP)
depth (m)
0
-10
-20
-30
-40
-50
-60
-70
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
20
15
10
5


observations (BBMP)
ROMS 2 (BBMP)
ROMS 23 (BBMP)
depth (m)
0
-10
-20
-30
-40
-50
-60
-70
Jan-14
Mar-14
May-14
Jul-14
Sep-14
Nov-14
Jan-15
Mar-15
May-15
Jul-15
Sep-15
Nov-15
20
15
10
5
0

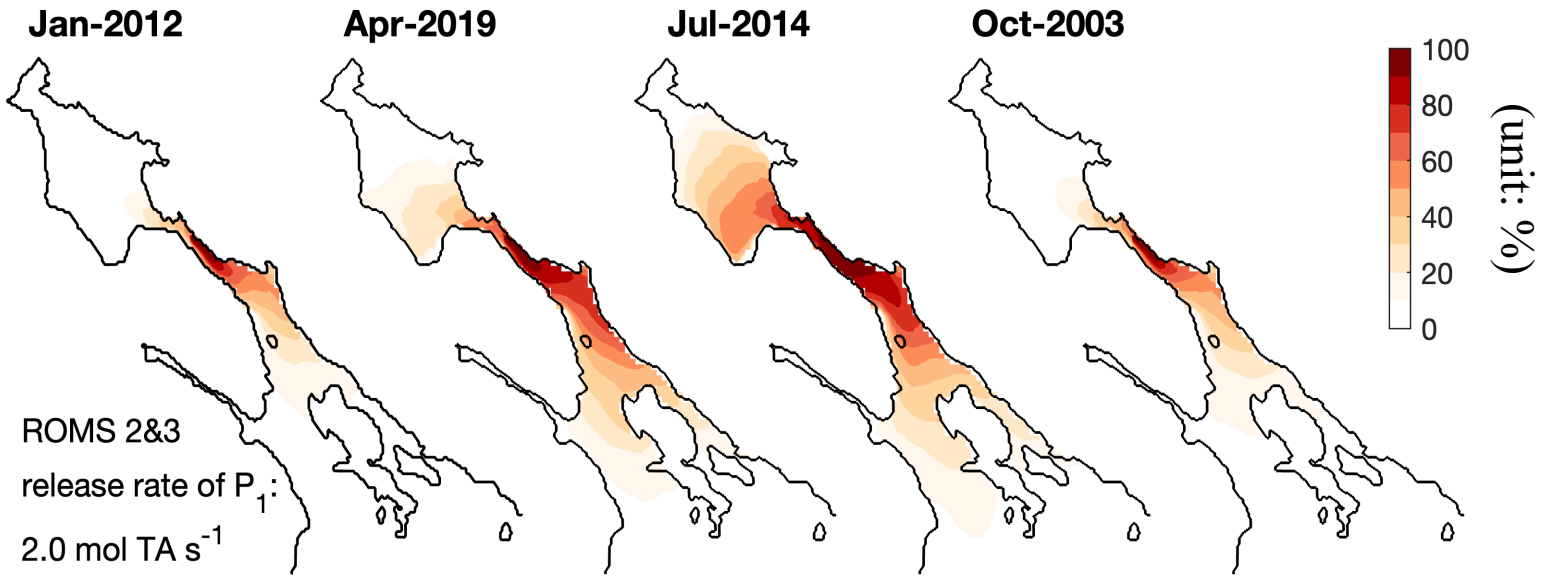


Residence time (days): $\boldsymbol{\tau = \int_0^{t_n} \frac{C(t)}{C_0} dt}$

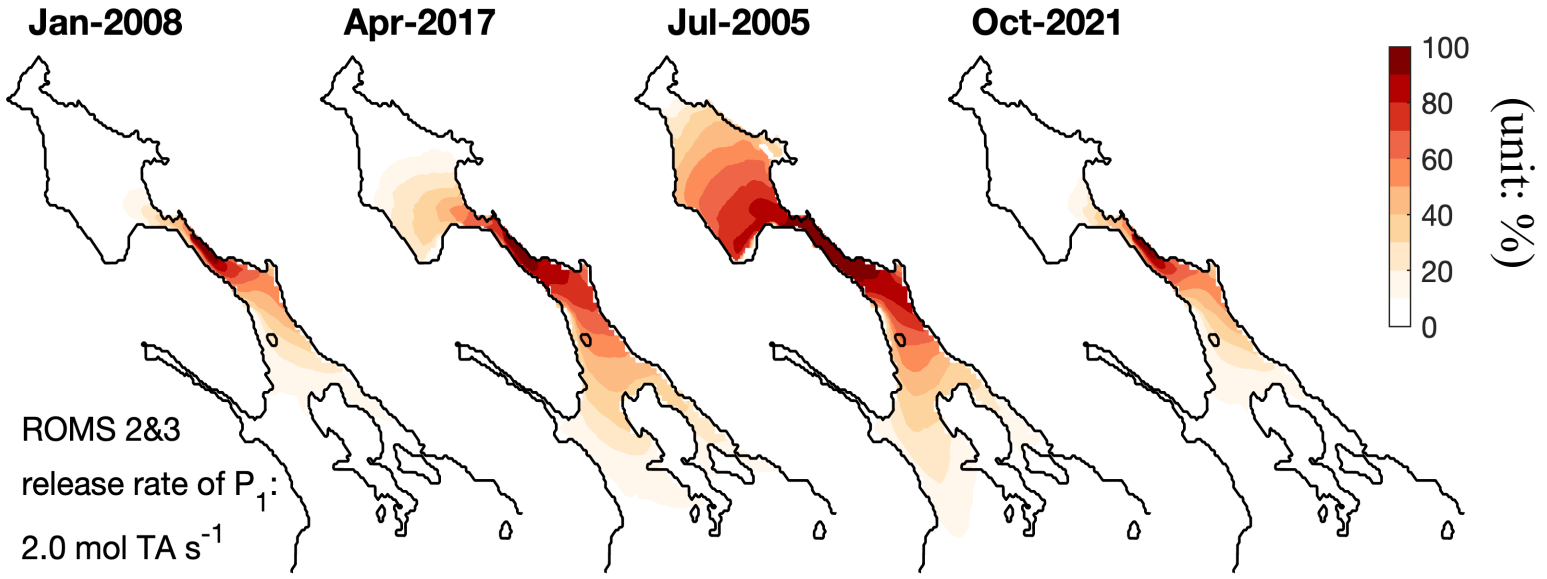
(Shen et al 2004)

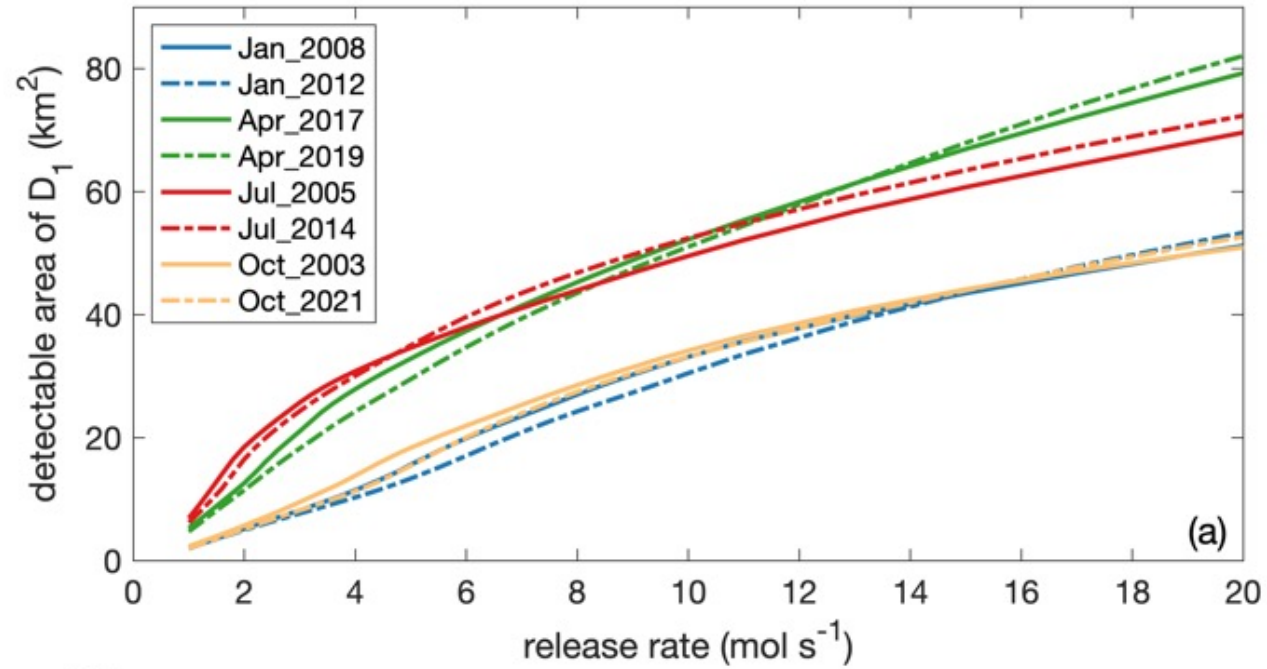


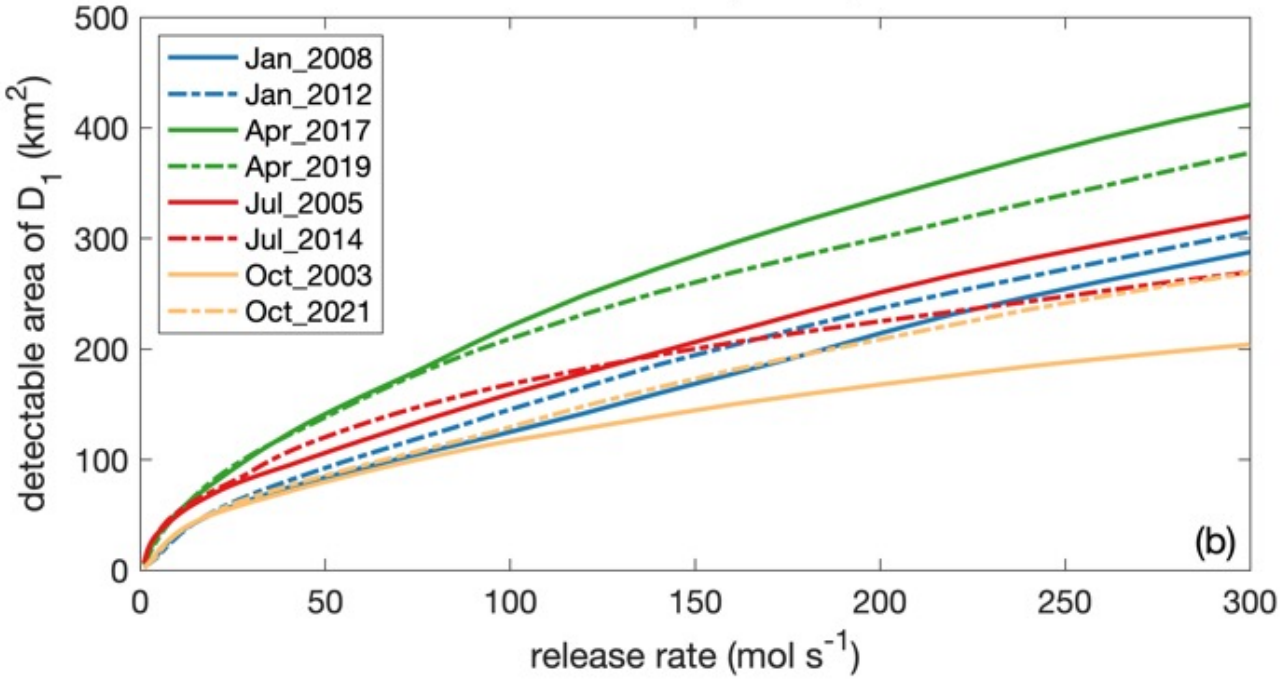
Shortest MRT



Longest MRT




Jan_2008
Jan_2012
Apr_2017
Apr_2019
Jul_2005
Jul_2014
Oct_2003
Oct_2021
detectable area of D1 (km2)
release rate (mol s-1)
(a)
0
20
40
60
80
0
2
4
6
8
10
12
14
16
18
20


Jan_2008
Jan_2012
Apr_2017
Apr_2019
Jul_2005
Jul_2014
Oct_2003
Oct_2021
detectable area of D1 (km2)
release rate (mol s-1)
(b)
0
100
200
300
400
500
0
50
100
150
200
250
300

Impact of dissolution rate and sinking velocity