Changes in drift pathways of fish eggs along the coast of Norway

Presented at
JONSMOD 2016-05-10 - 12

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MET Norway

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Outline

- Background: Biological controversy

- Approaches for simulation of fish egg drift

- Model configuration

- Method 1: Tracers

- Method 2: On-line Lagrangian floats

- Method 3: Off-line model for egg & larva

- Testing, comparing methods

- Changes in time

- Concluding remarks

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Controversy:

Cod spawning is shifting northward; *why?*
Climate or fishing? Heated debate!

Spatial shifts in spawning habitats of Arcto-Norwegian cod related to multidecadal climate oscillations and climate change

Svein Sundby and Odd Nakken

biology letters
Marine biology

Biol. Lett. (2010) 6, 261–264
doi:10.1098/rsbl.2009.0789
Published online 18 November 2009

Fisheries change spawning ground distribution of northeast Arctic cod

Anders Frugård Opdal*
Department of Biology, University of Bergen, PO Box 7803,

Global Change Biology

Global Change Biology (2015) 21, 2465–2466, doi: 10.1111/gcb.12925

LETTER

Comment to 'Opdal AF, Jørgensen C (2015) Long-te change in a behavioural trait: truncated spawning distribution and demography in Northeast Arctic Global Change Bi...214, 1521–1530, doi: 10.11 gcb.12773'

SVEIN SUNDBY
Institute of Marine Research and Hj...

Global Change Biology

Global Change Biology (2014), doi: 10.1111/gcb.12773

Long-term change in a behavioural trait: truncated spawning distribution and demography in Northeast Arctic cod

ANDERS FRUGÅRD OPDAL[1] and CHRISTIAN JØRGENSEN[2]
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Global Cha...

Global Change Biology (2015), doi: 10.1111/gcb.12977

RESPONSE

Response: Demography affects spawning location in Northeast Arctic cod, but what affects demography?

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Climate vs. harvesting

Climate hypothesis:

➢ Cod migrate south
to give larvae a warm start
(faster growth ⇒
   higher survival)

➢ Higher temperatures ⇒
less benefit in migrating far
 ⇒ northward shift

1980s – present

1910s–1940s and 1980s – present

1950s–1970s

1950s – 1970s

Sundby &
Nakken (2008),
ICES JMS

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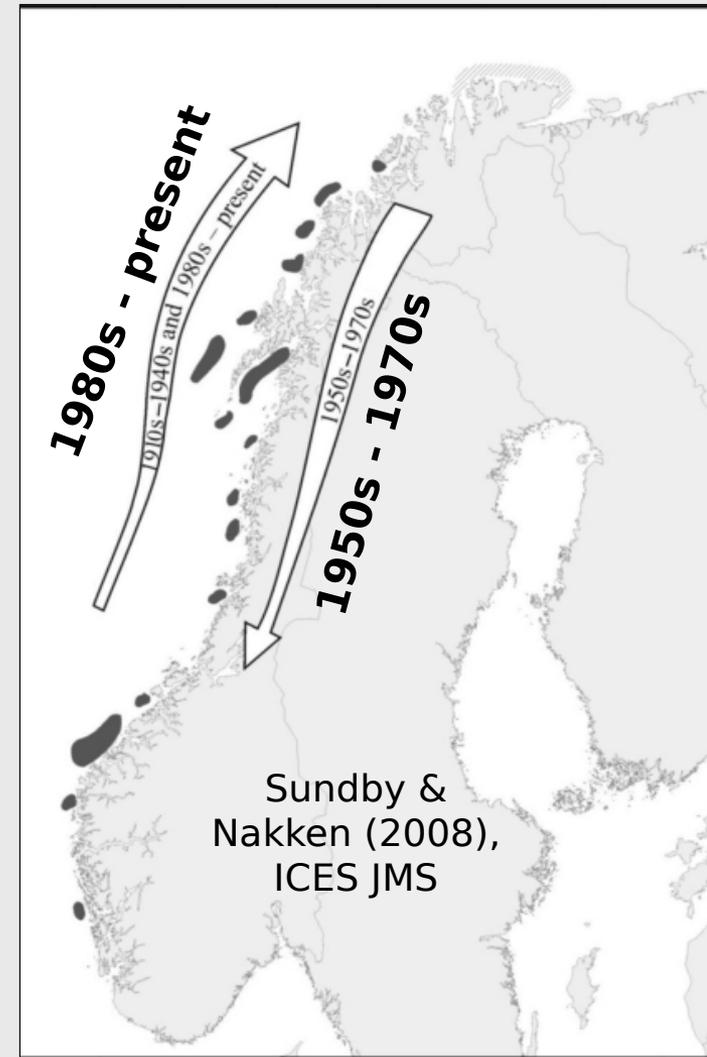
Climate vs. harvesting

Harvesting hypothesis:

➢ Disproportional removal of large individuals

➢ Large individuals migrate greater distances

➢ Few large individuals $\Rightarrow$ spawning shifts closer to Barents Sea feeding grounds

1980s - present

1910s–1940s and 1980s – present

1950s–1970s

1950s - 1970s

Sundby & Nakken (2008), ICES JMS

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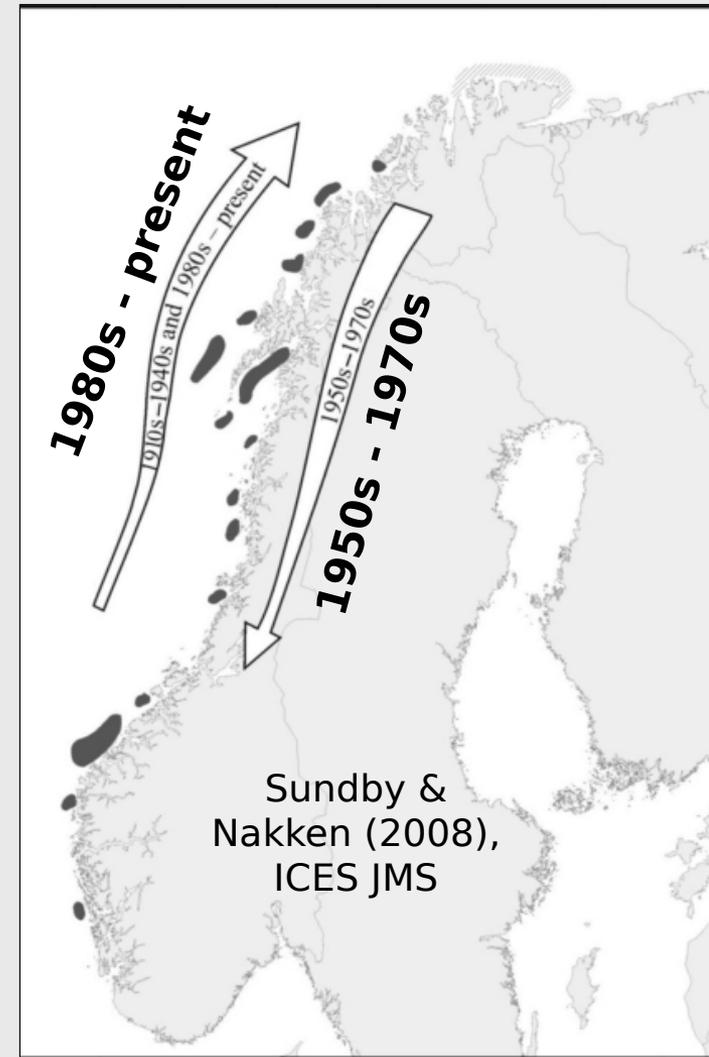
Approach: Drift model + survey data

➤ Combine dataset with hydro-dynamical model for drift of cod eggs

➤ Link egg observations with different spawning grounds

➤ Examine conditions (mainly temperature) along drift pathways

From which spawning ground(s) do the observed eggs originate?

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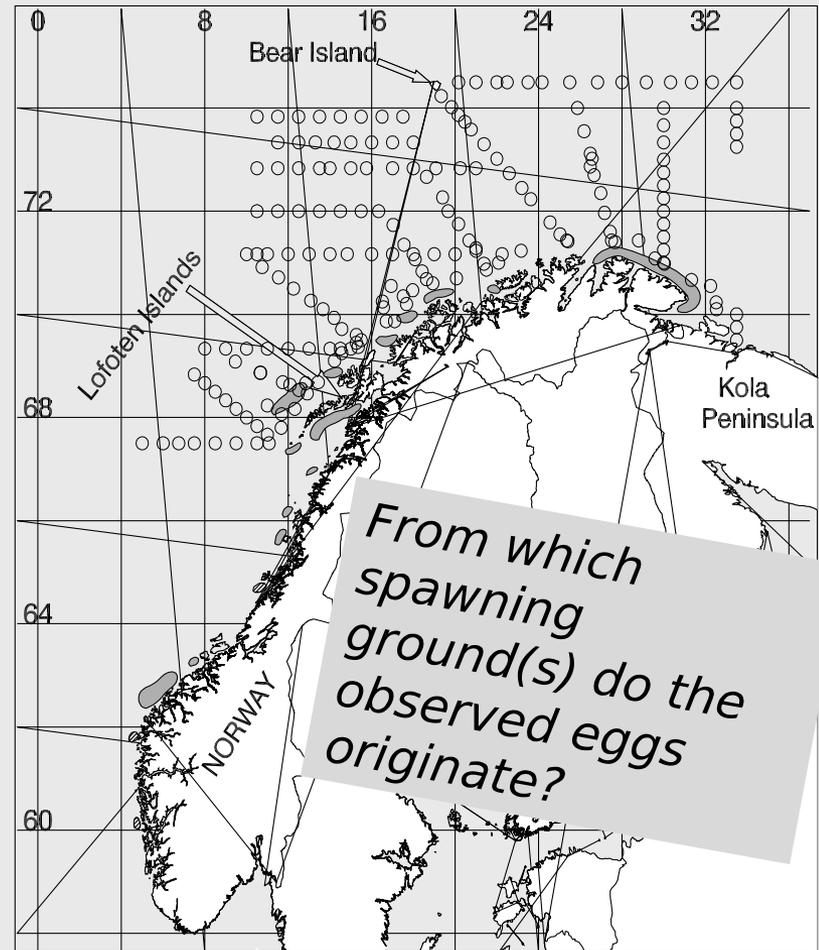
Drift of fish eggs in circulation models

Earlier attempt («*SVIM*»):   - «model particles» advected
by daily mean currents, in
z-levels (4 km configuration)
- an excessive fraction of the
«model particles» beached
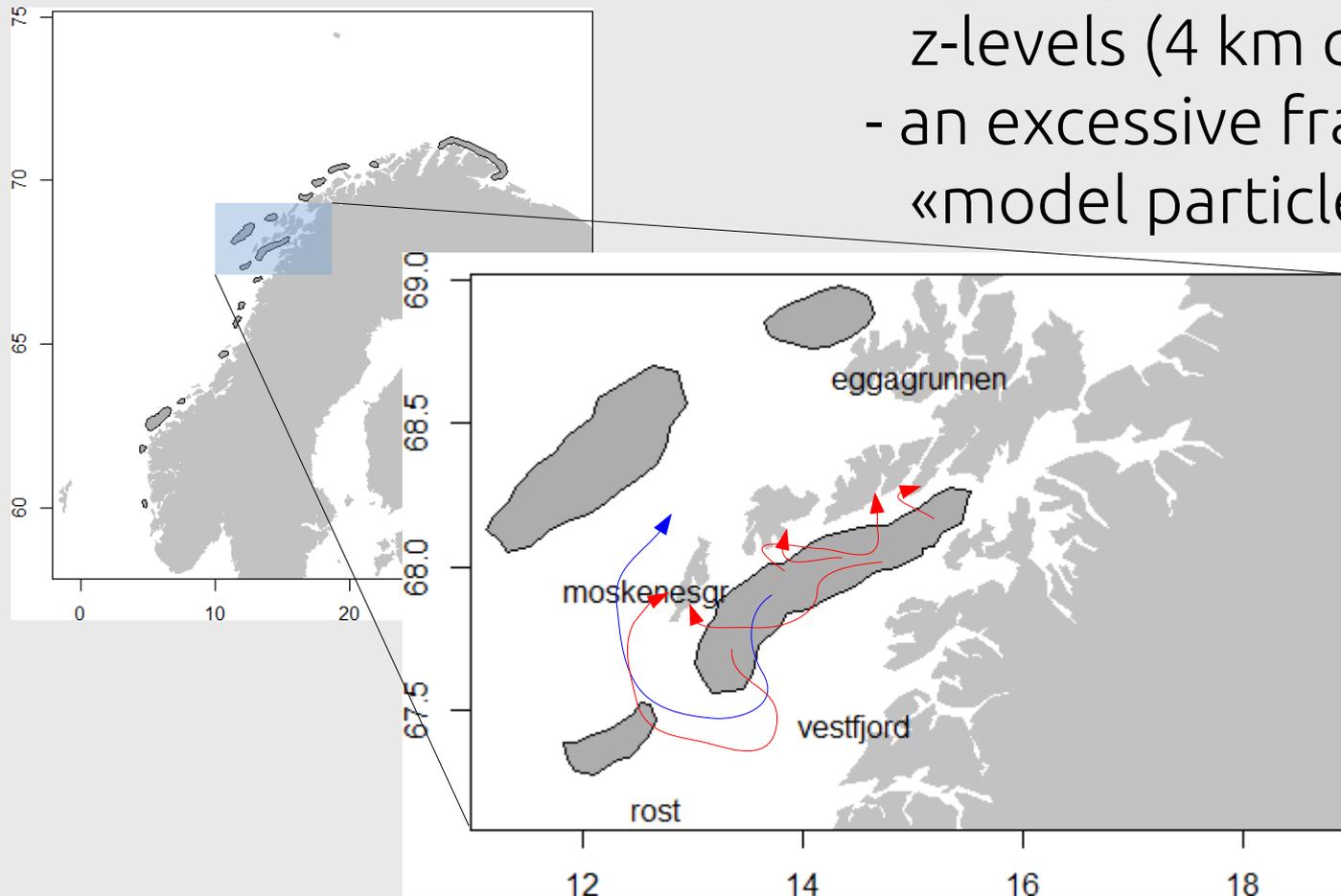
Drift of fish eggs in circulation models

(1) Tracers
   Released at chosen times into the simulation

(2) On-line Lagrangian drift («floats»)
   Particles that move with 3D currents after seeding

(3) Off-line egg & larvae model
   Particles whose behaviour change when eggs becom larvae

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Circulation model: ROMS

2 configurations:

SUSTAIN-0.8	Horizontal resolution:	800m
SUSTAIN-4.0	Horizontal resolution:	4km

Vertical resolution: 36 *s* levels

Vertical mixing: GLS

Tracer advection: MPDATA (positive definite)

OBC: From earlier 4km config. *«SVIM»*
                      (which used SODA at boundaries)

Atm. forcing: Bulk fluxes from NORA (regional
                      down-scaling of ERA-40/interim)

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Notable change in *SUSTAIN-x.x* from earlier *«SVIM»*-configuration:

Vertical structure
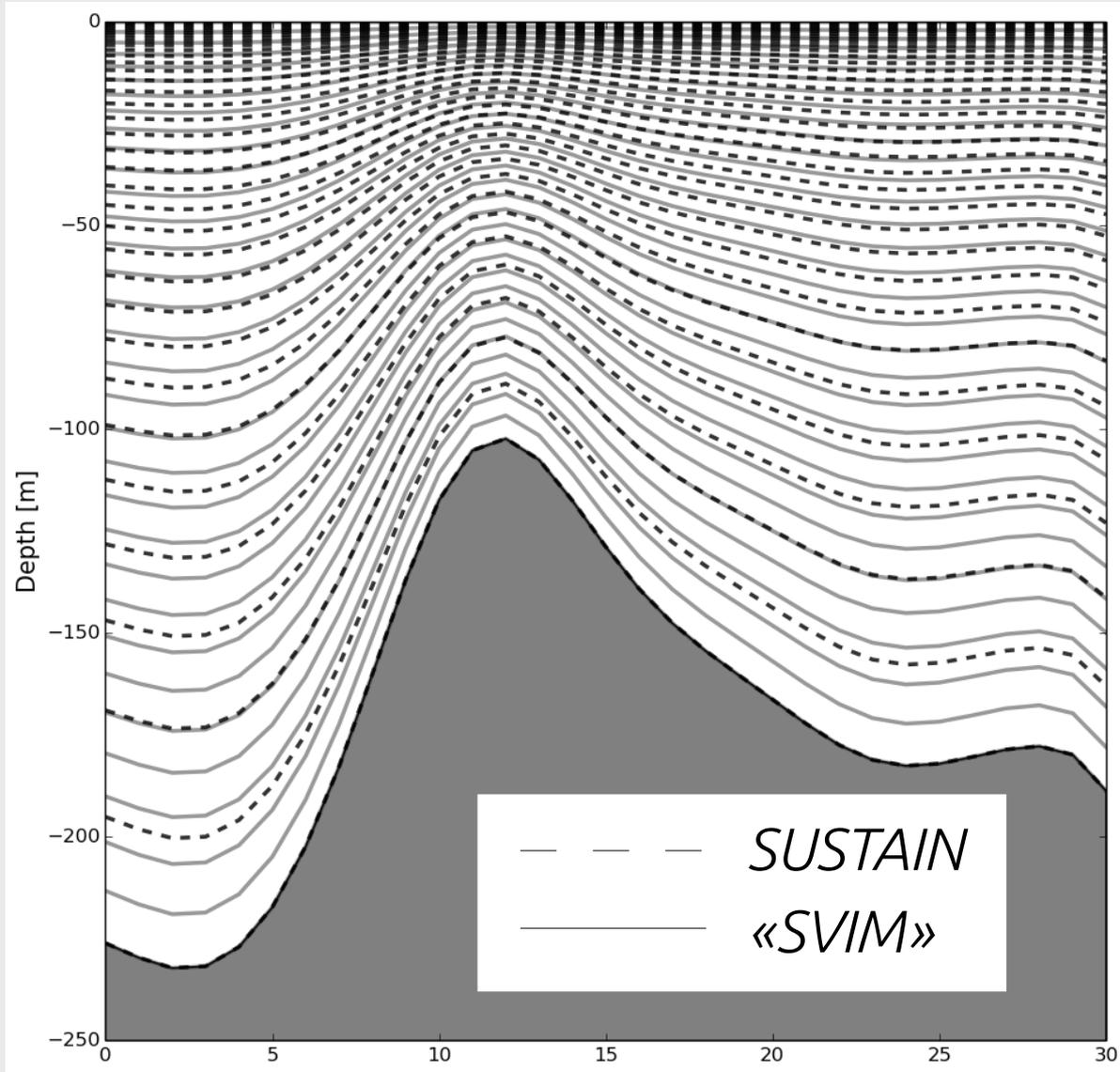
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Circulation model: ROMS

Rationale for changing the vertical structure:
Reduce pressure gradient problem

Proxy: Haney number

Change in Haney no.:
*SUSTAIN - «SVIM»*

Circulation model: ROMS

Rationale for changing the vertical structure:
Reduce pressure gradient problem

Proxy: Haney number

Haney no. in *SUSTAIN-0.8*
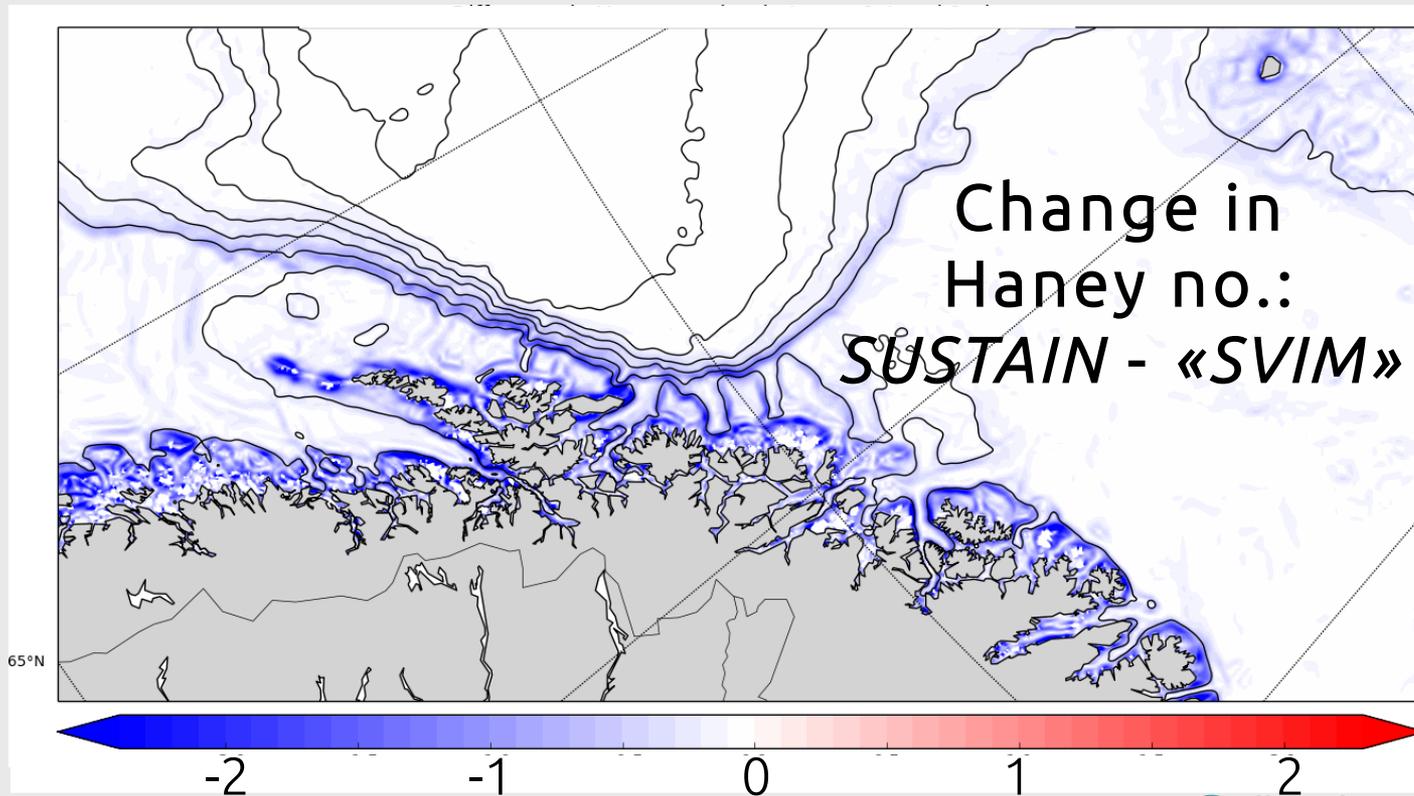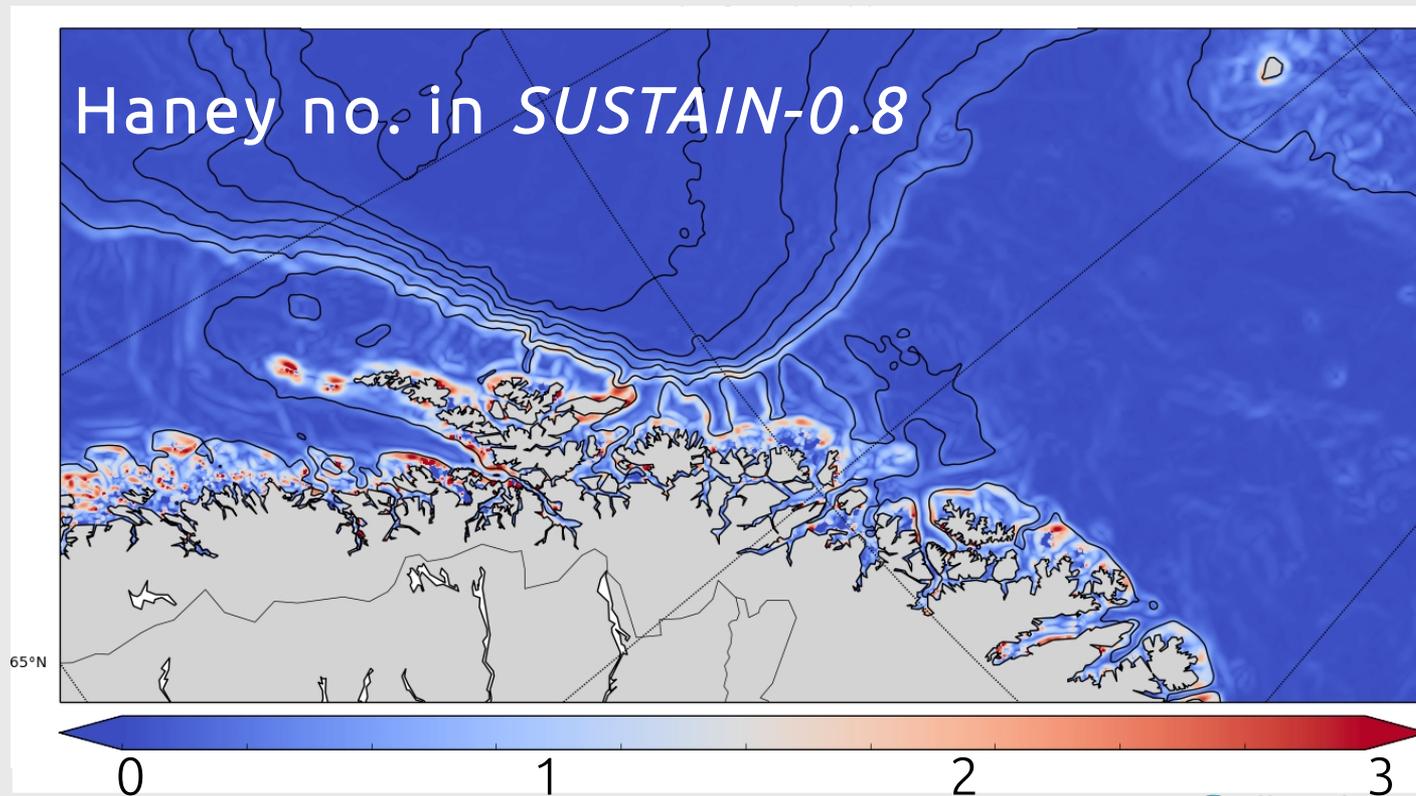
Circulation model: ROMS

Model domains, bottom topography

SUSTAIN-0.8

SUSTAIN-4.0

40 100 200 500 1000 2000

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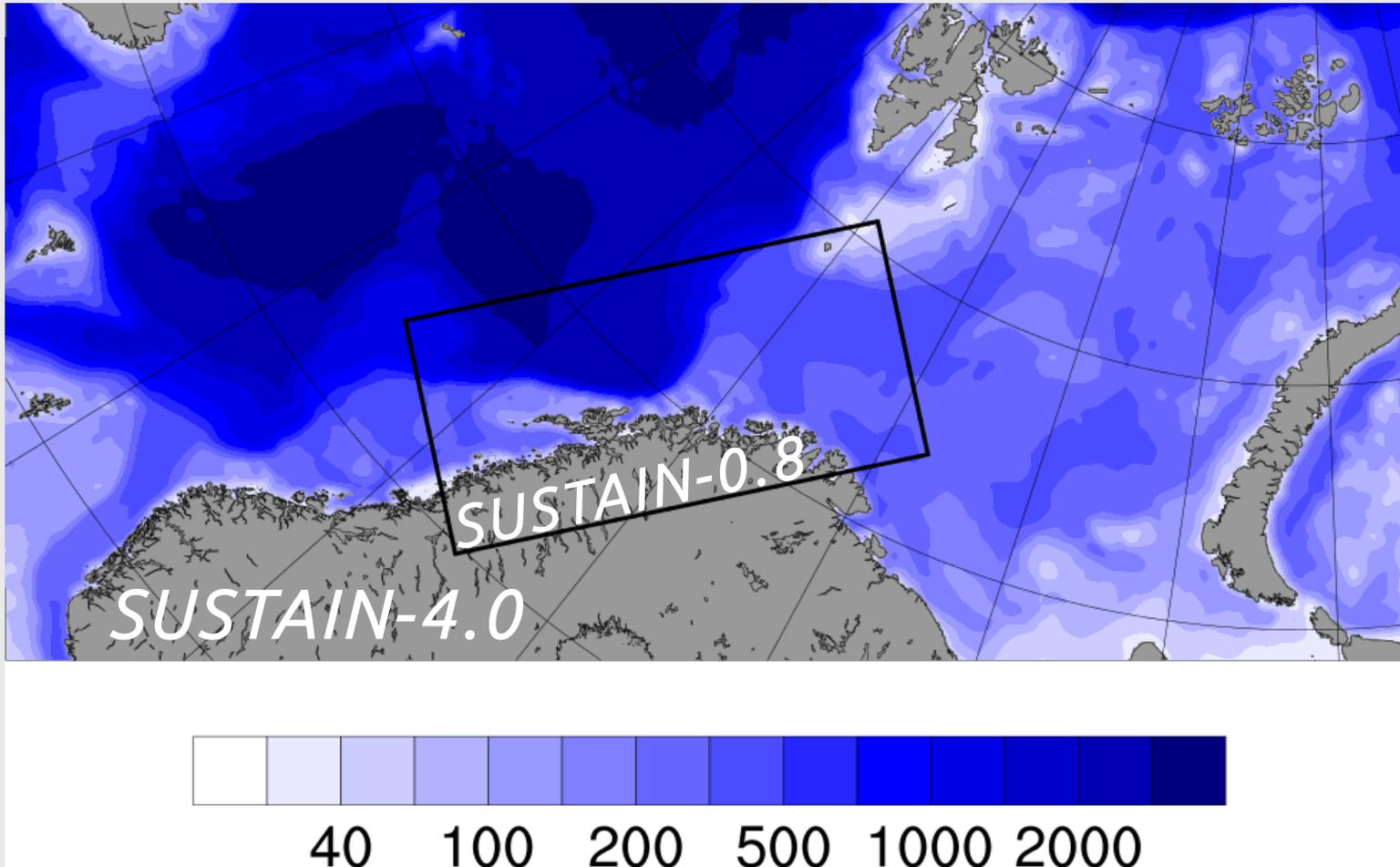
Circulation model: ROMS

Selection of spawning grounds for the present study

Yttersida

Vestfjorden

Møre

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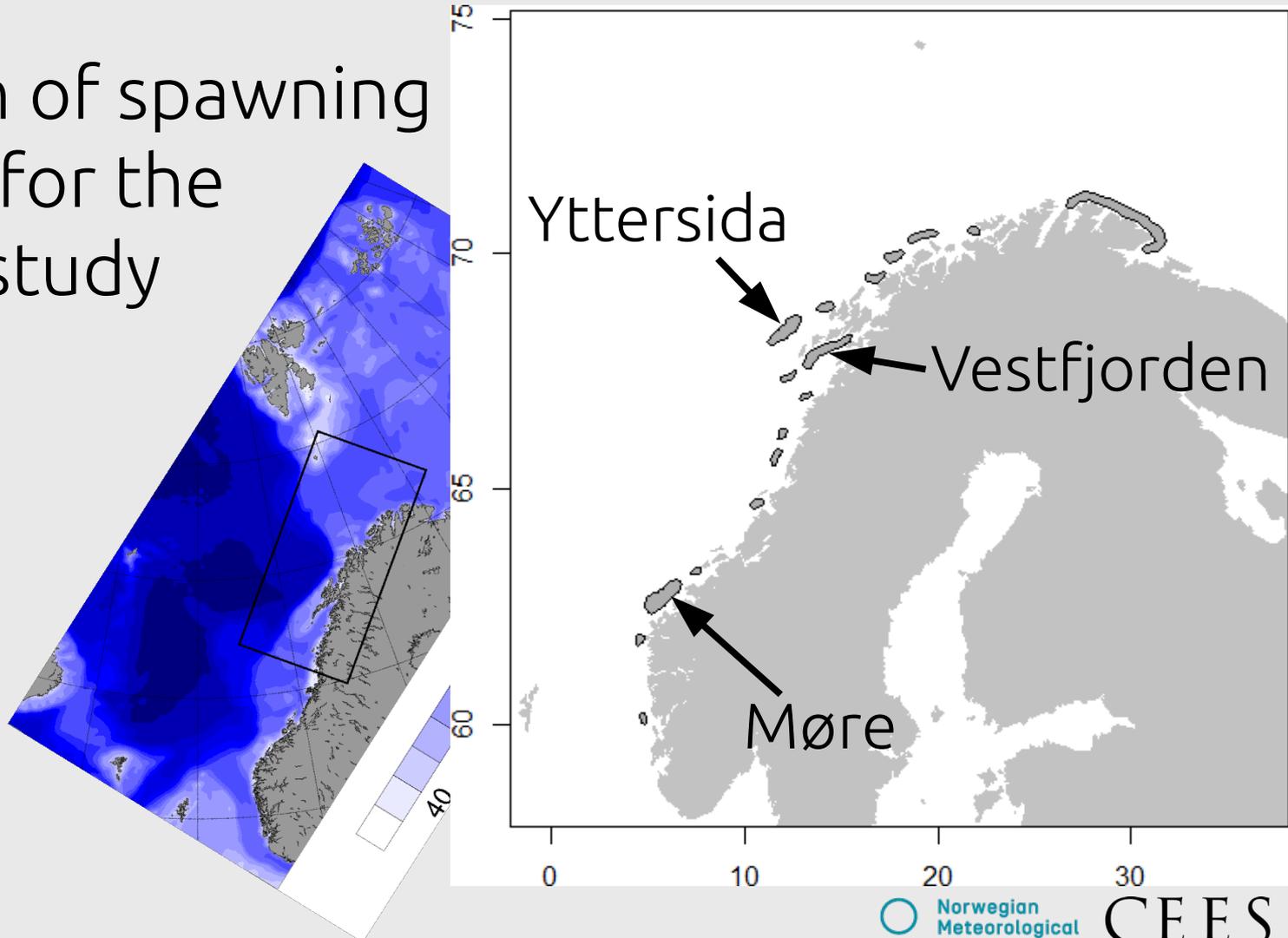
Tracer representation of fish eggs

Initial tracer profile, float depths

0m

-50m
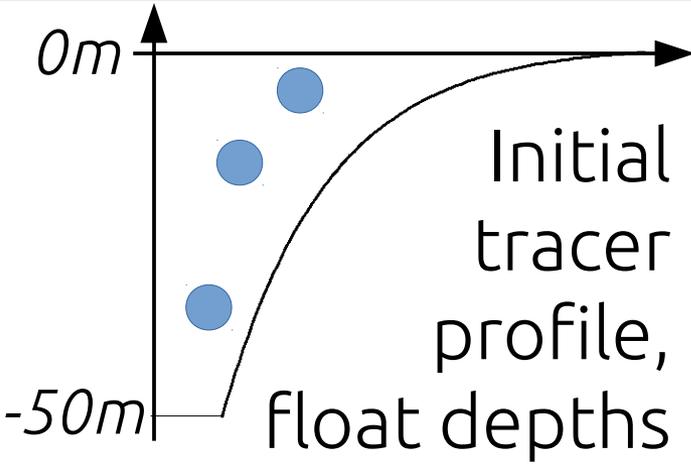
Initial spawning grounds in model (*SUSTAIN-4.0*)

Yttersida

Møre

Vestfjorden

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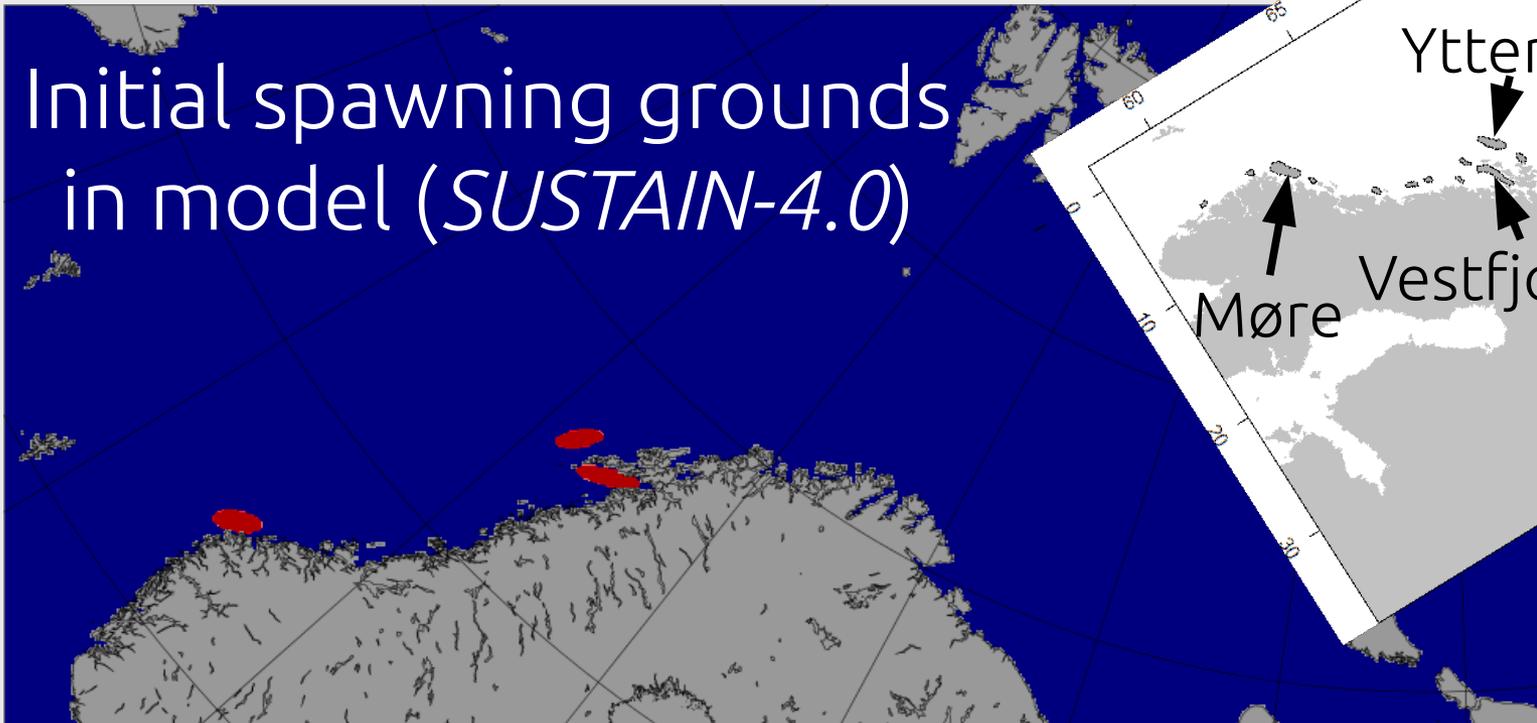
Tracer representation of fish eggs
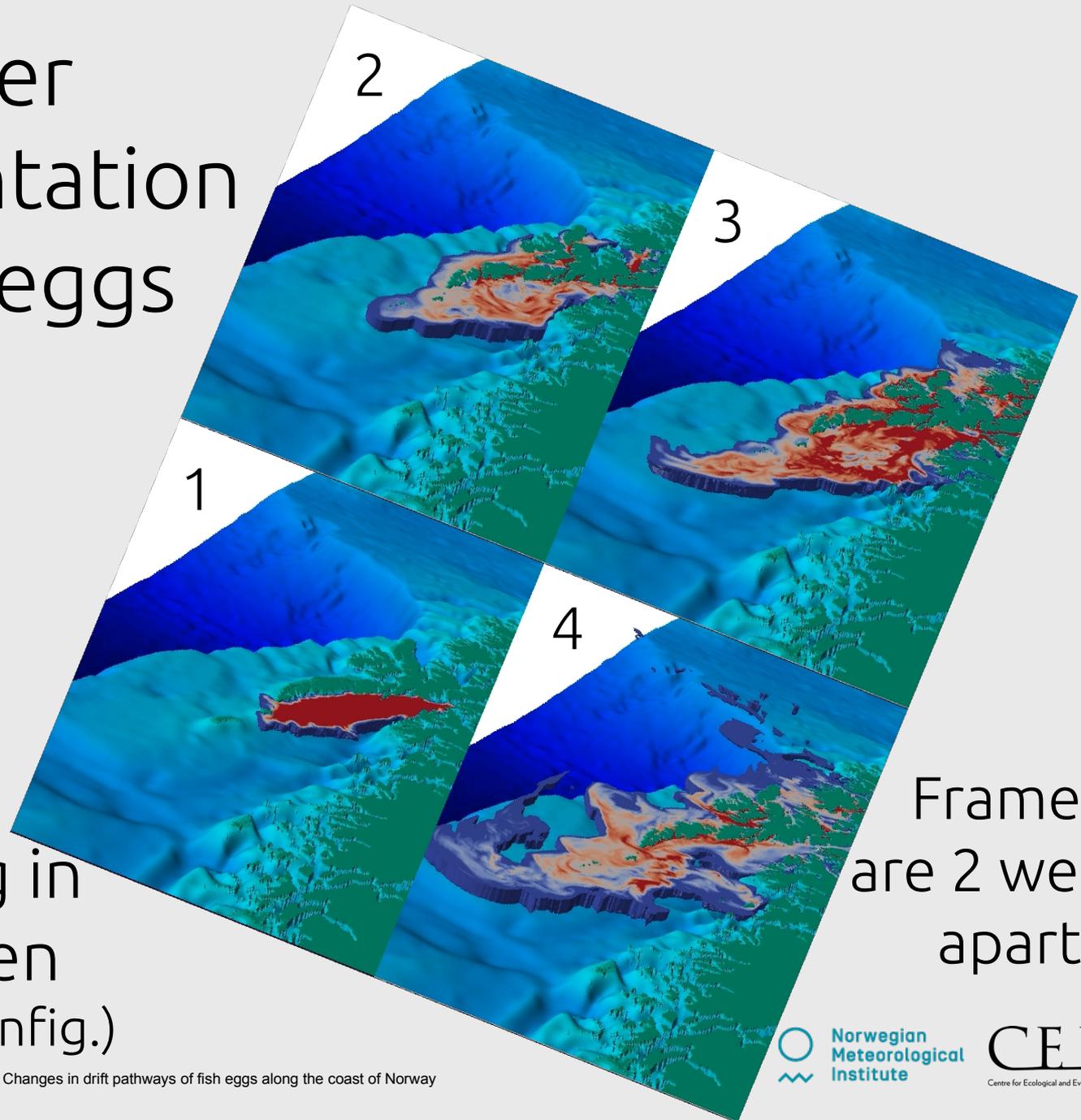
Tracer originating in Vestfjorden
(*SUSTAIN-0.8* config.)

Frames are 2 weeks apart

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Fish eggs represented by Lagrangian floats

## Initial spawning position of model floats (*SUSTAIN-4.0* ; depths: 5m, 15m, 35m)

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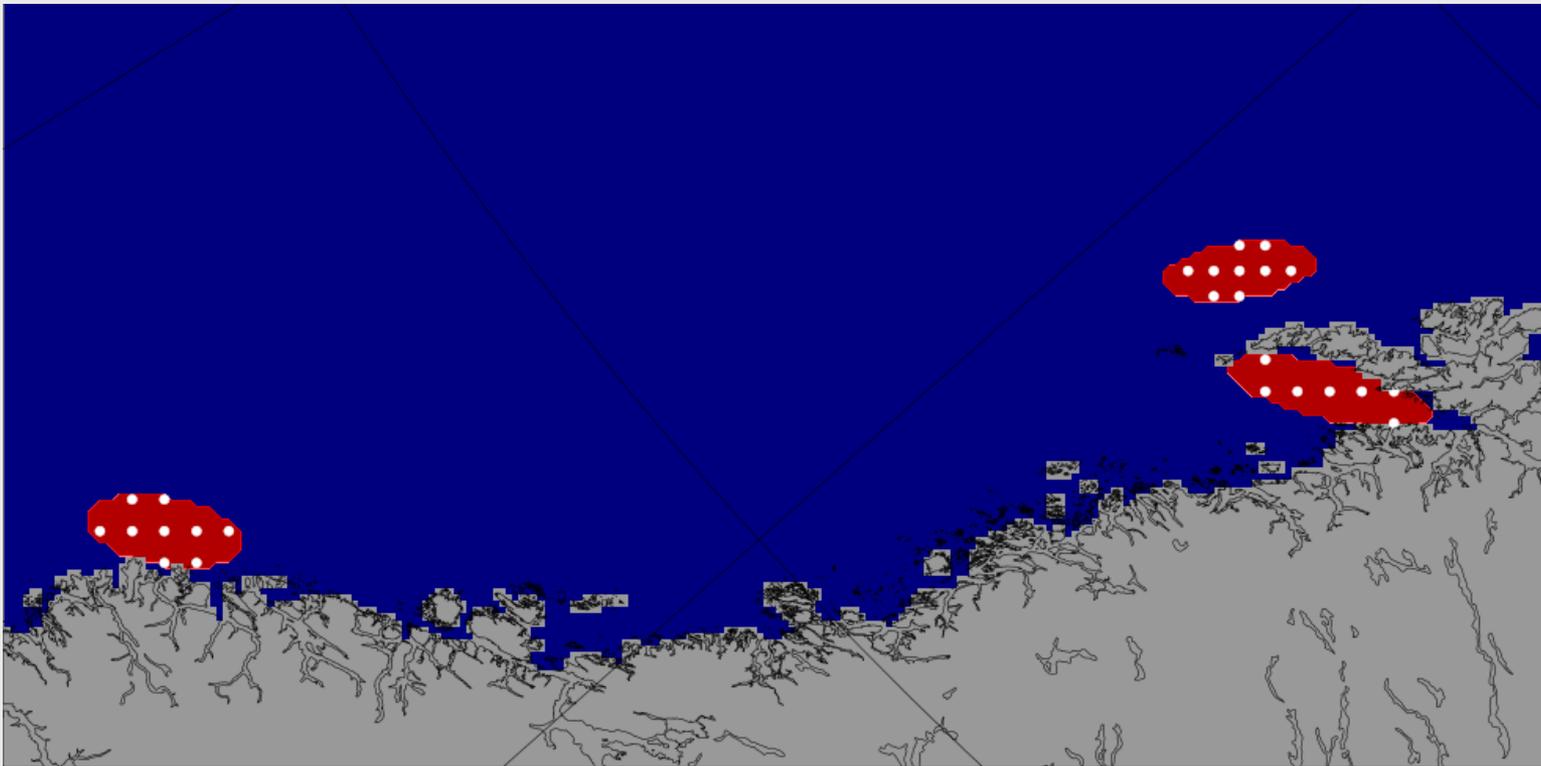
Fish eggs represented by Lagrangian floats

Five drift trajectories, with a
12 hour seeding separation

Changes in drift pathways of fish eggs along the coast of Norway
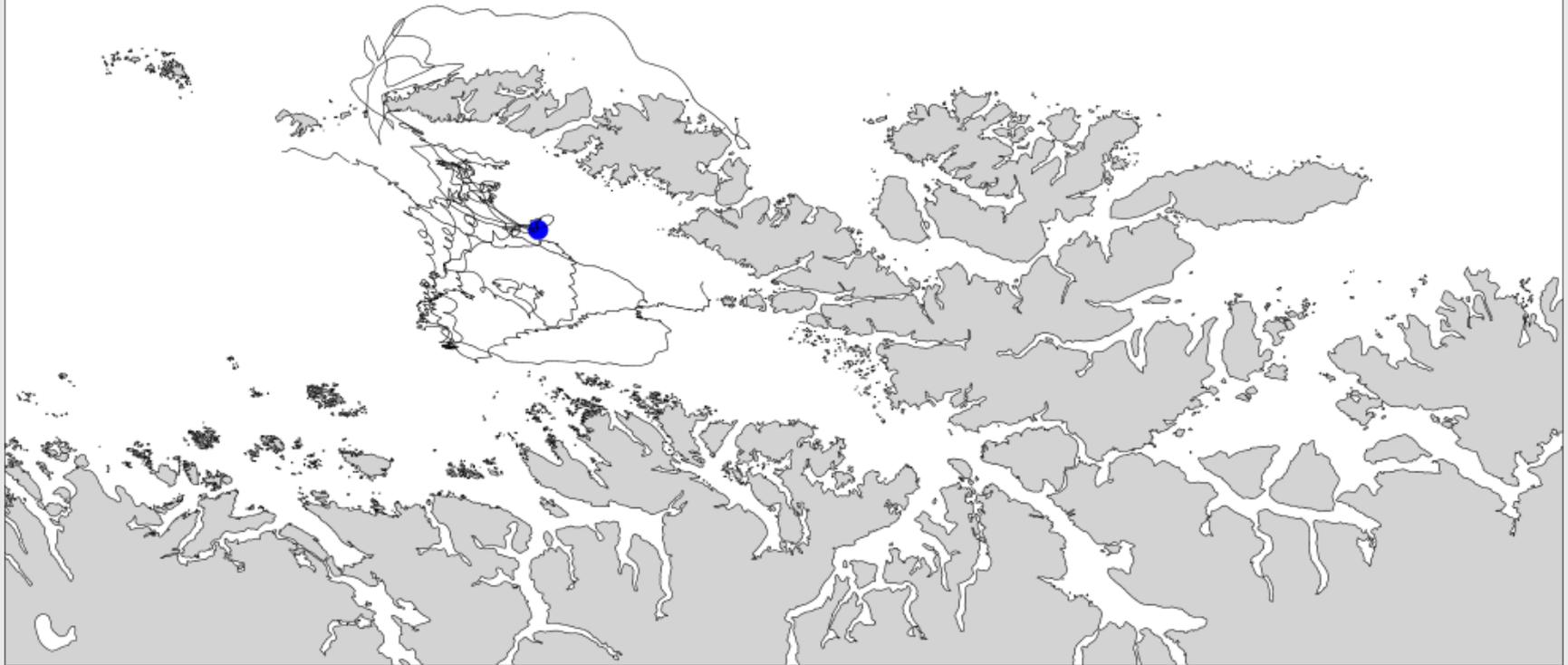
Fish eggs represented by Lagrangian floats

31 drift trajectories, with a 12 hour seeding separation

Changes in drift pathways of fish eggs along the coast of Norway

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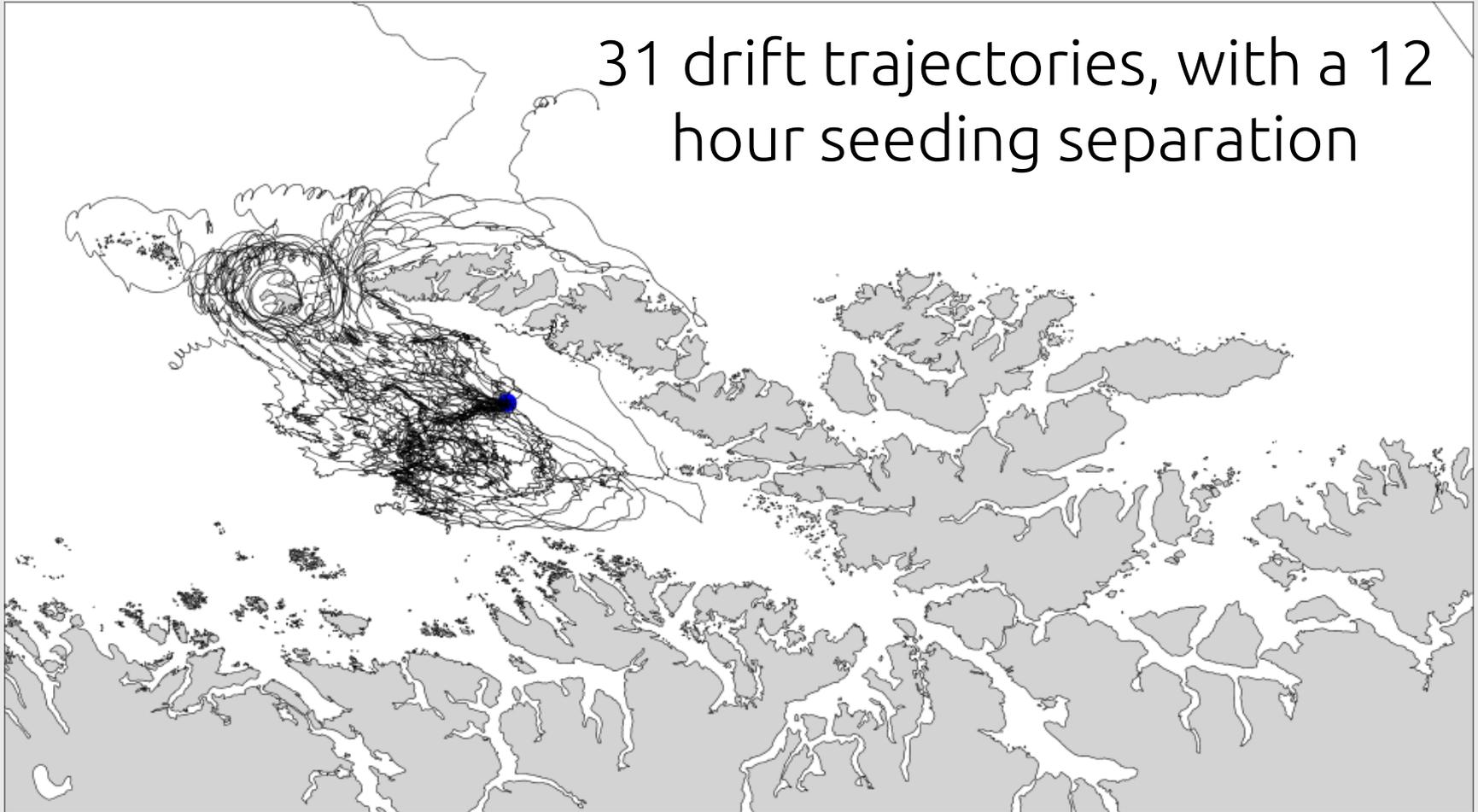
LADIM:
An off-line model for advection and dispersion of fish eggs and larvae
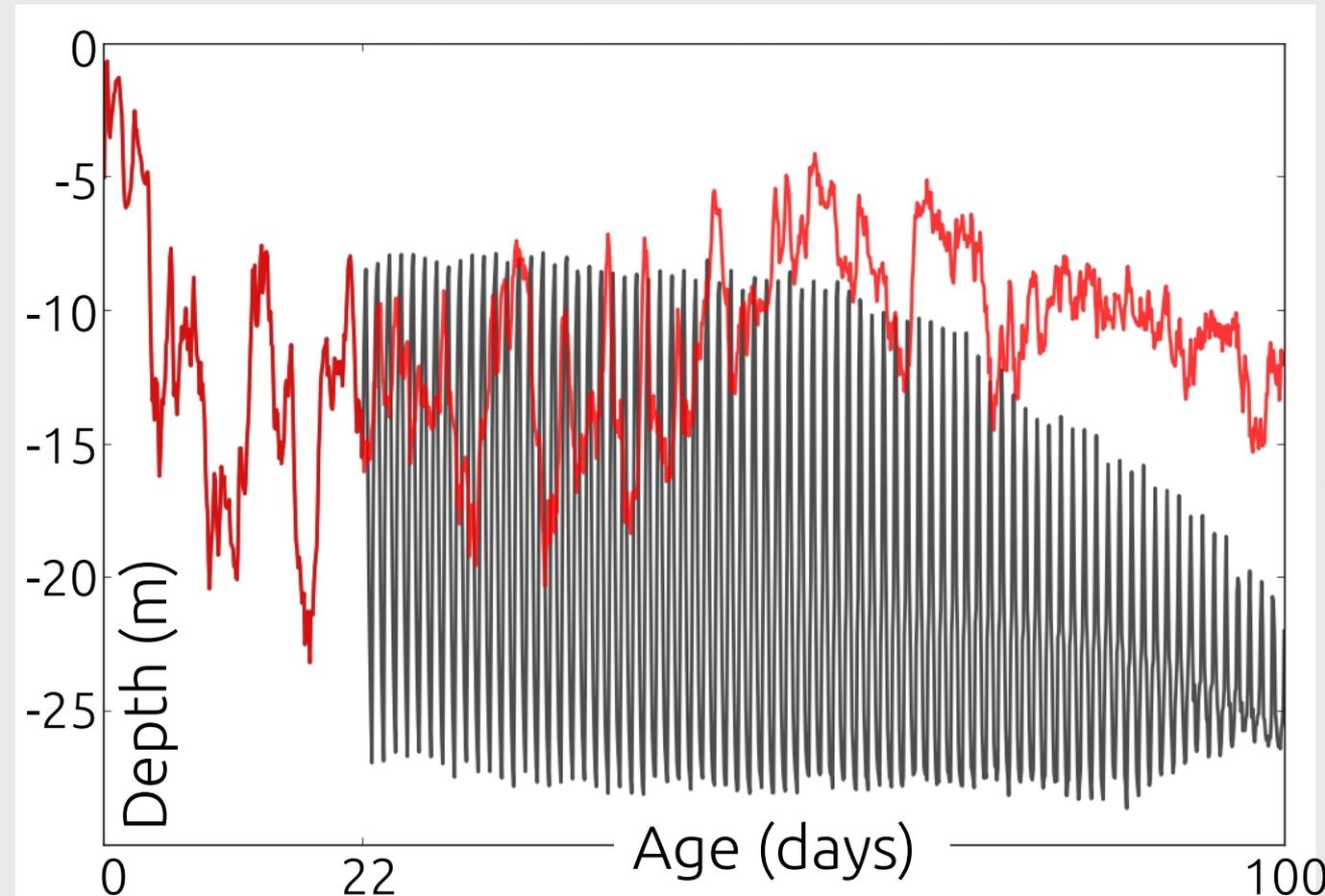
There's biology!
eggs-only
eggs → larvae

Testing, comparing methods
Fish eggs & larvae in LADIM *vs.* ROMS floats

Seeding
positions in
Vestjorden;
SUSTAIN-0.8
(12)

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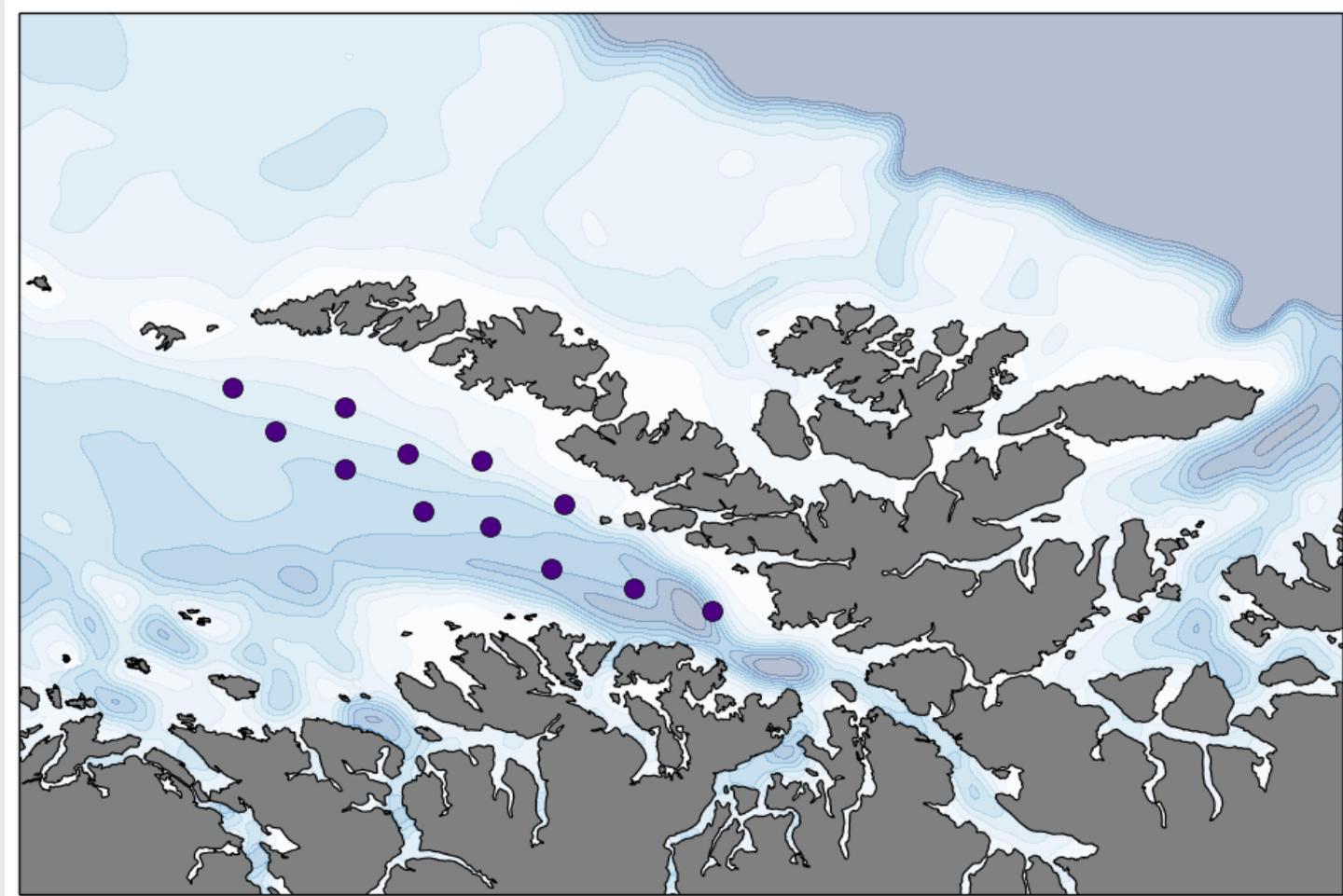
Testing, comparing methods
Fish eggs & larvae in LADIM *vs.* ROMS floats
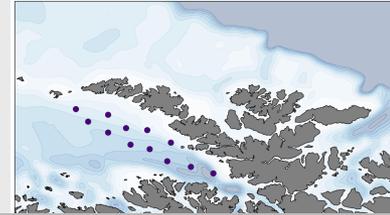
Positions of particles seeded on March 1
after 61 days'
   drift

LADIM (36·40)
LADIM-eggs
ROMS (36)
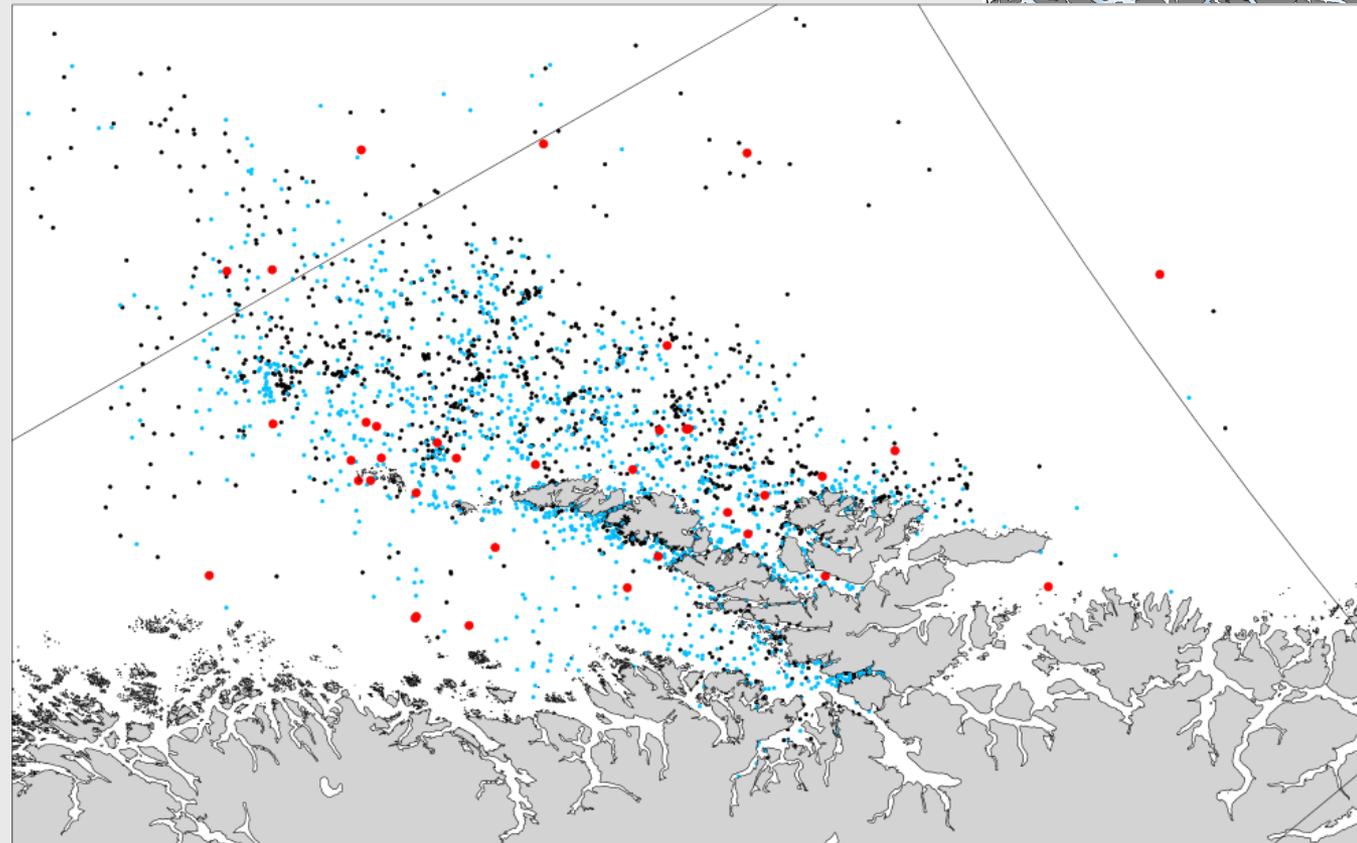
SUSTAIN-08
1992

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Testing, comparing methods
ROMS tracer results *vs.* ROMS floats

Cross-section at 69.5 ºN
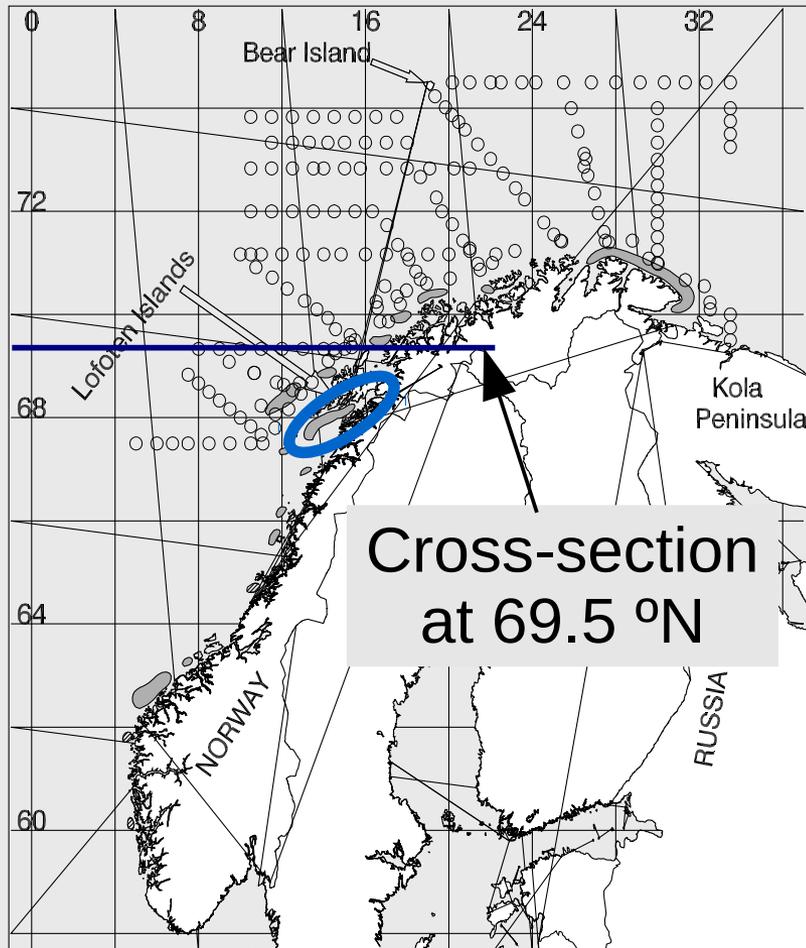
- How swiftly do eggs reach the cross-section?
- What is the fraction that makes it across?

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Testing, comparing methods
ROMS tracer results *vs.* ROMS floats
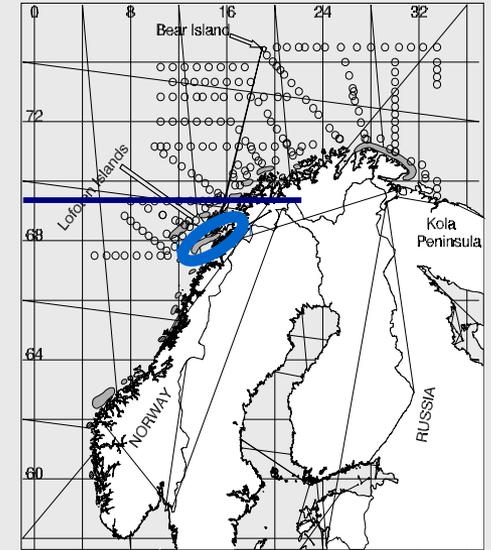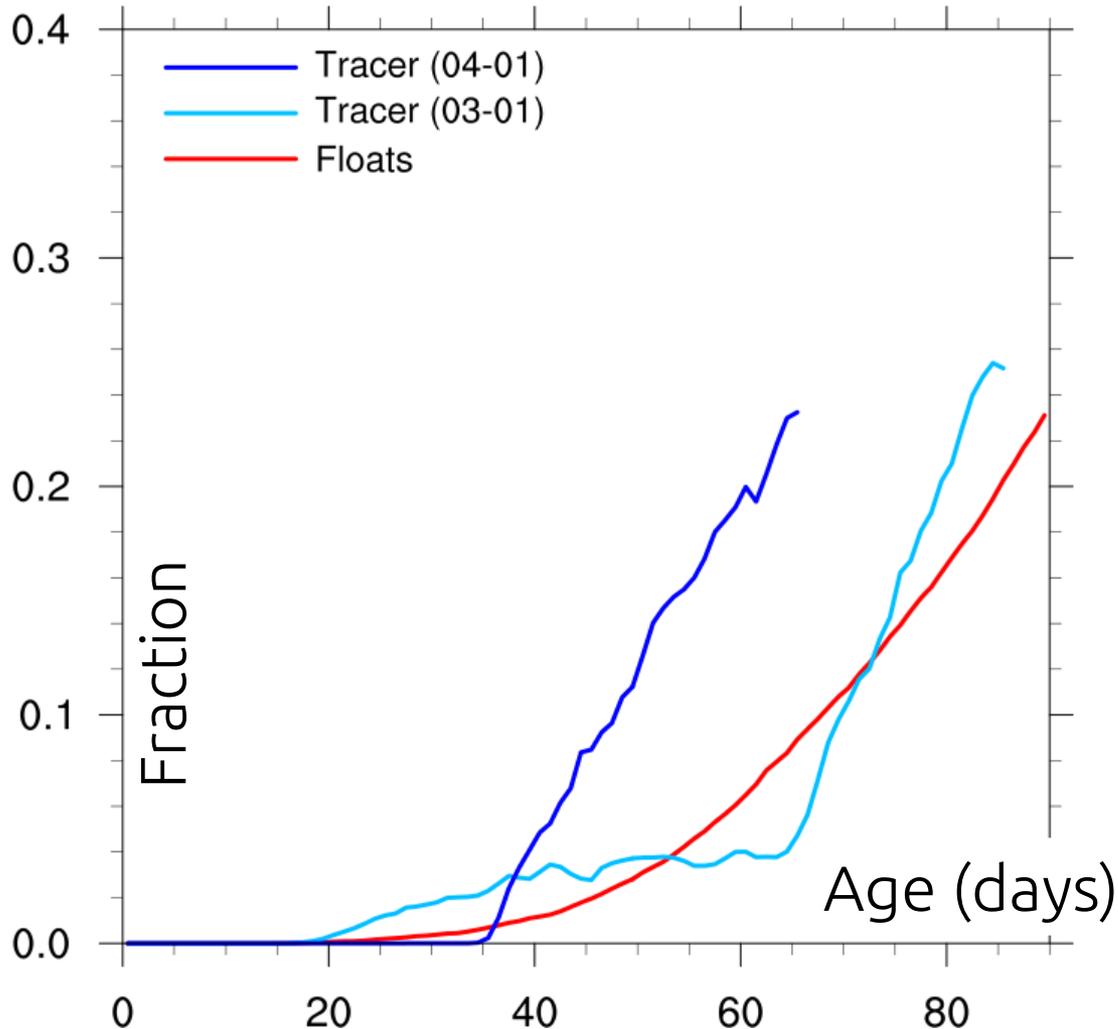
Results from the simulation period 1992-03 – 1992-06 (*SUSTAIN-0.8*)

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Testing, comparing methods
ROMS tracer results *vs.* ROMS floats
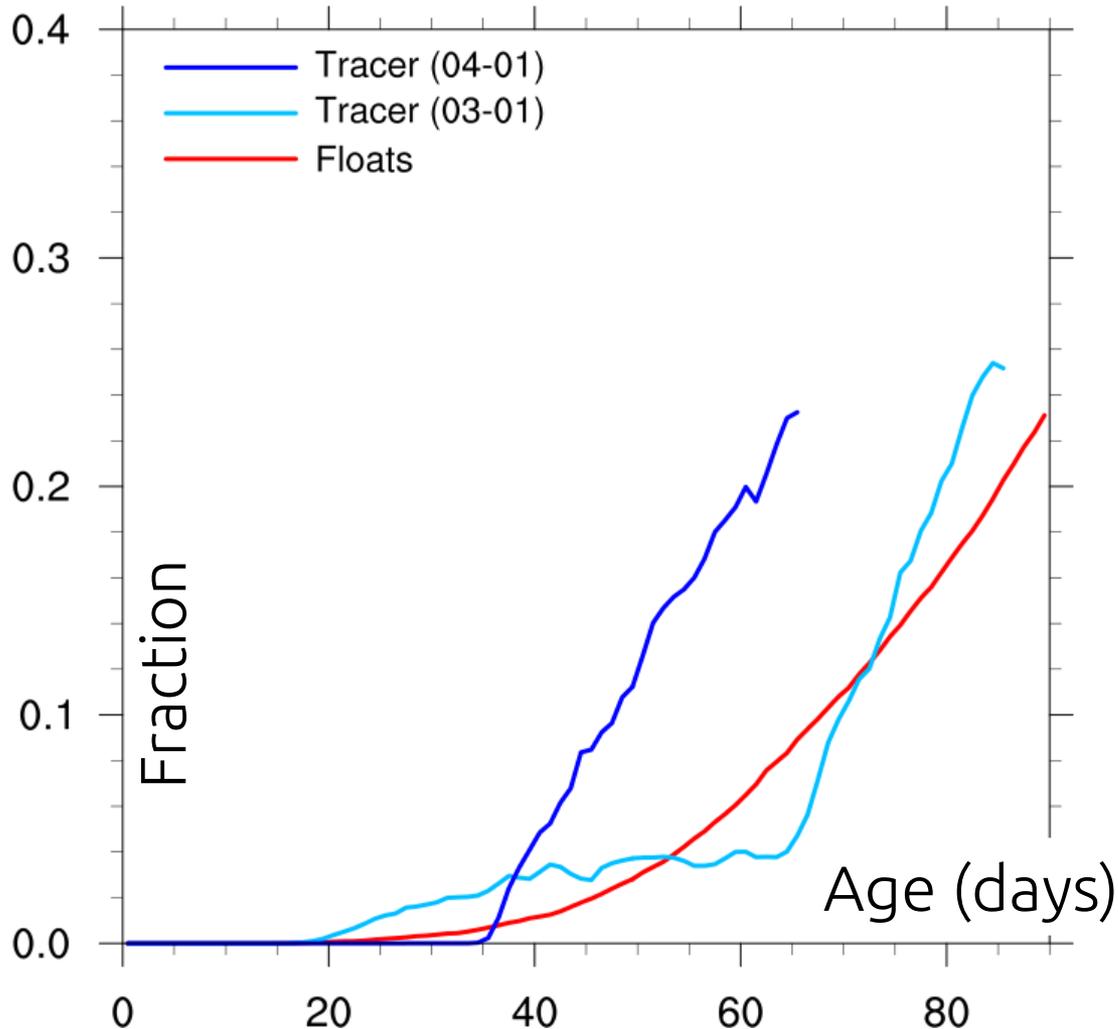
A tendency for tracers to drift faster to 69.5 °N than floats

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Testing, comparing methods
ROMS tracer results *vs.* ROMS floats

SUSTAIN-0.8 *SUSTAIN-4.0*

Mixed!
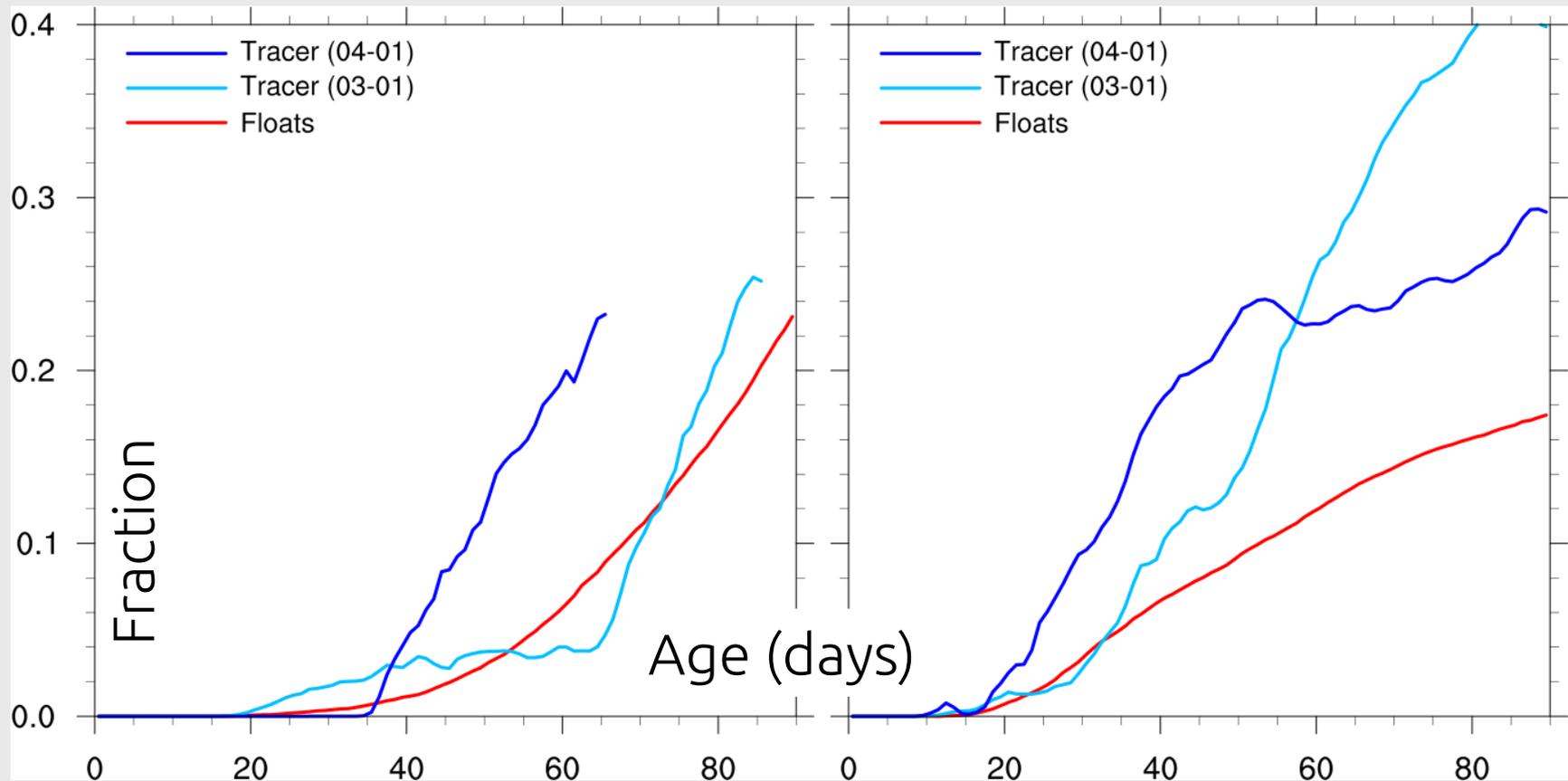
Testing, comparing methods
ROMS tracer results *vs.* ROMS floats
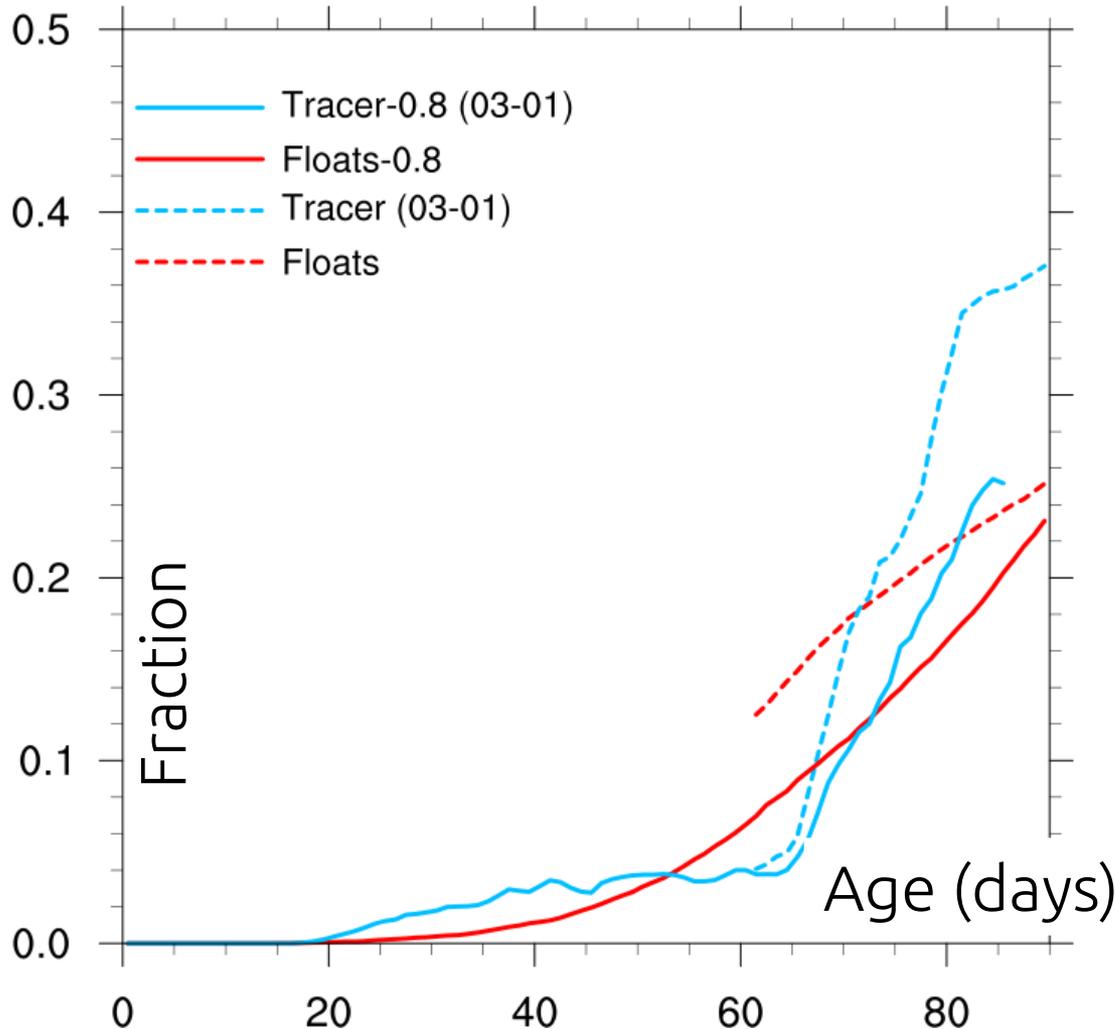
Moving results from *SUSTAIN-0.8* to *SUSTAIN-4.0*

Tracer concentration tranfserred after 60 days

Floats transferred after 30-60 days

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Changes in time

Results from the simulation period 03 – 06 (*SUSTAIN-0.8*)


Contrasts!
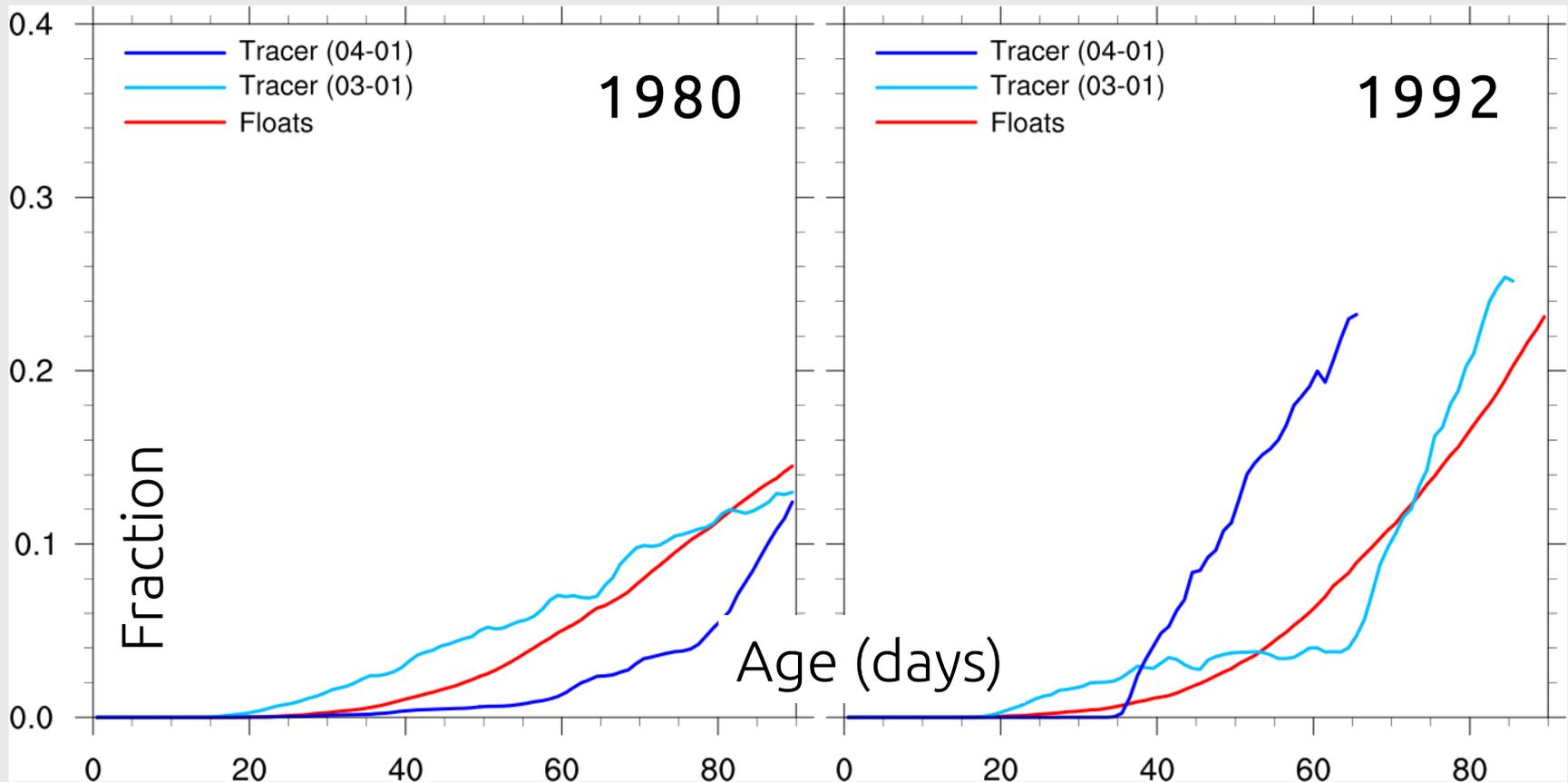
Changes in time: *Staying warm*
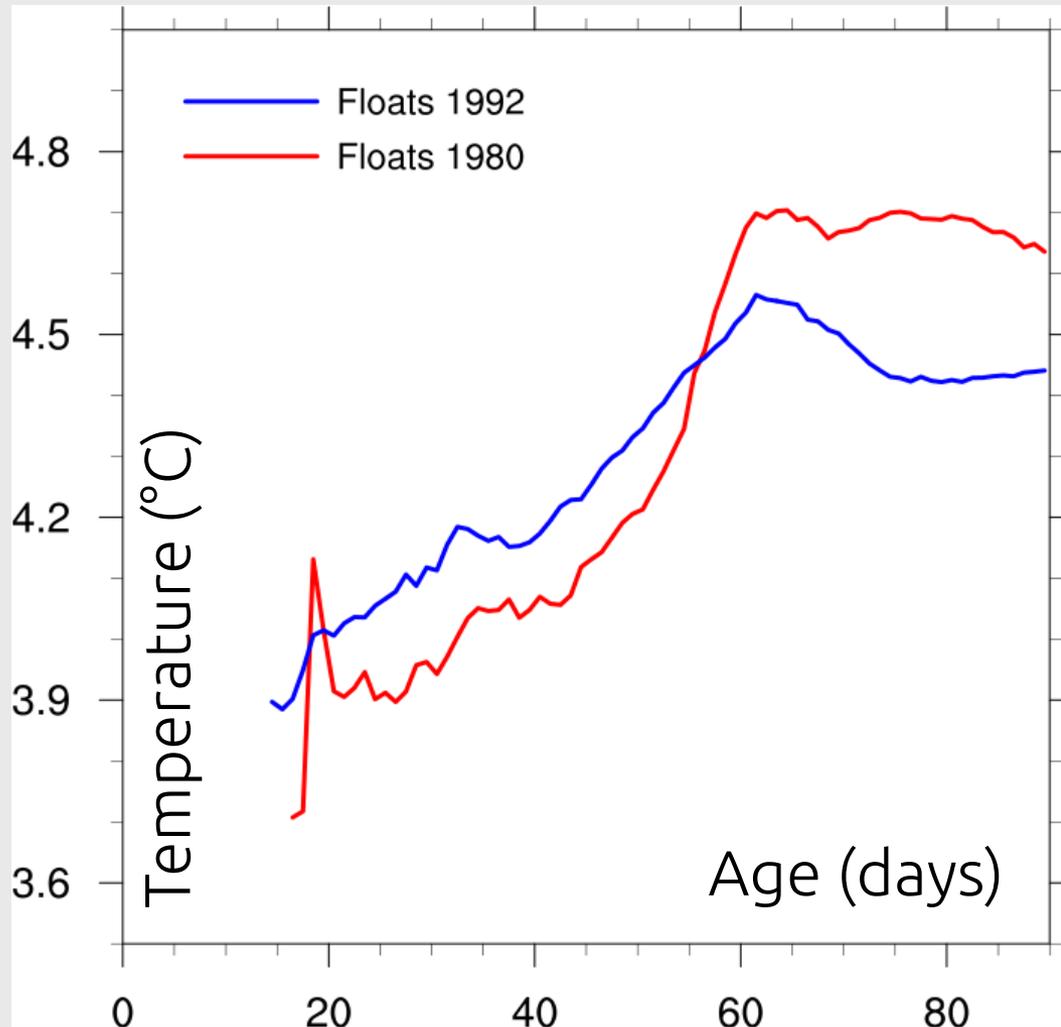
Average temperature of particles north of 69.5 °N.

Results are from the simulation period 03 – 06 (*SUSTAIN-0.8*)

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Changes in time: *Avoiding predators*
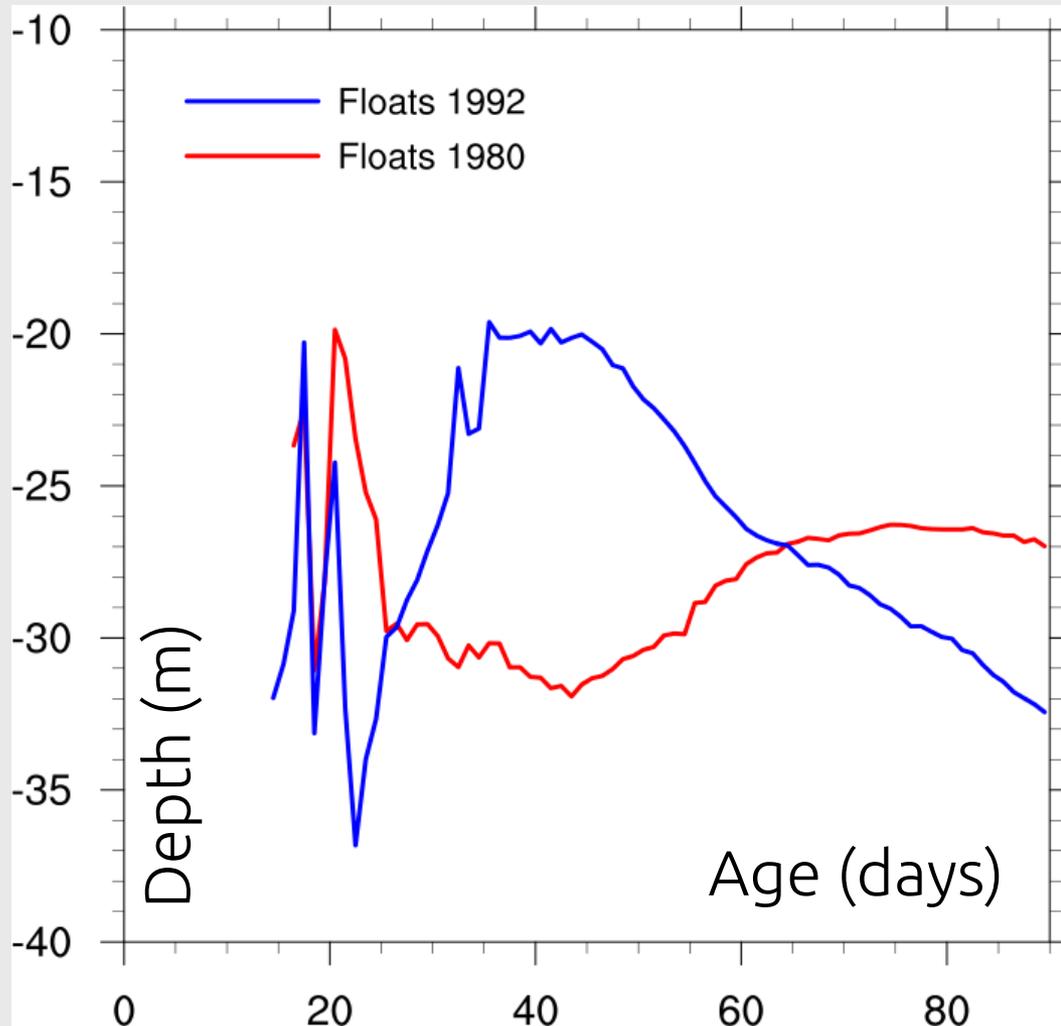
Average depth of particles north of 69.5 °N.

Results are from the simulation period 03 – 06 (*SUSTAIN-0.8*)

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Concluding remarks

- 3 different approaches to simulating drift of fish eggs have been tested

- The approaches provide complementary information with drift results

- No inconsistency between different approaches have been discovered

- Initial results indicate that cod eggs experience contrasting conditions in different years

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- A good foundation for subsequent collaborations with biologists now exists

- The full set of simulations has not yet been completed

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