NKS-B NORCOP-COAST

Workshop on nuclear icebreaker traffic and transport of radioactive materials along the Nordic coastline: response systems and cooperation to handle accidents

13-14 October 2015, Tromsø, Norway

Simulation of pollutant dispersion along the oceanic food chain with CODE/eco_CODE

Kai Logemann & Guðrún Marteinsdóttir
University of Iceland

Effects of dynamic behaviour of Nordic marine environment to radioecological assessments (NKS-B EFMARE)

Roskilde meeting 26.-28.8.2015

Halldórsson Óskar, Geislavarnir Rikisins, Iceland
Iosjpe Mikhail, Norwegian Radiation Protection Authority, Norway
Isaksson Mats, University of Gothenburg, Sweden
Joensen Hans Pauli, Fróðskaparsetur Føroya, Faroe Islands
Logemann Kai, University of Iceland, Iceland
Roos Per, Technical University of Denmark, Denmark
Suolanen Vesa, Technical Research Centre of Finland, Finland
Thomas Rimon, University of Gothenburg, Sweden
Vartti Vesa-Pekka, Radiation and Nuclear Safety Authority, Finland

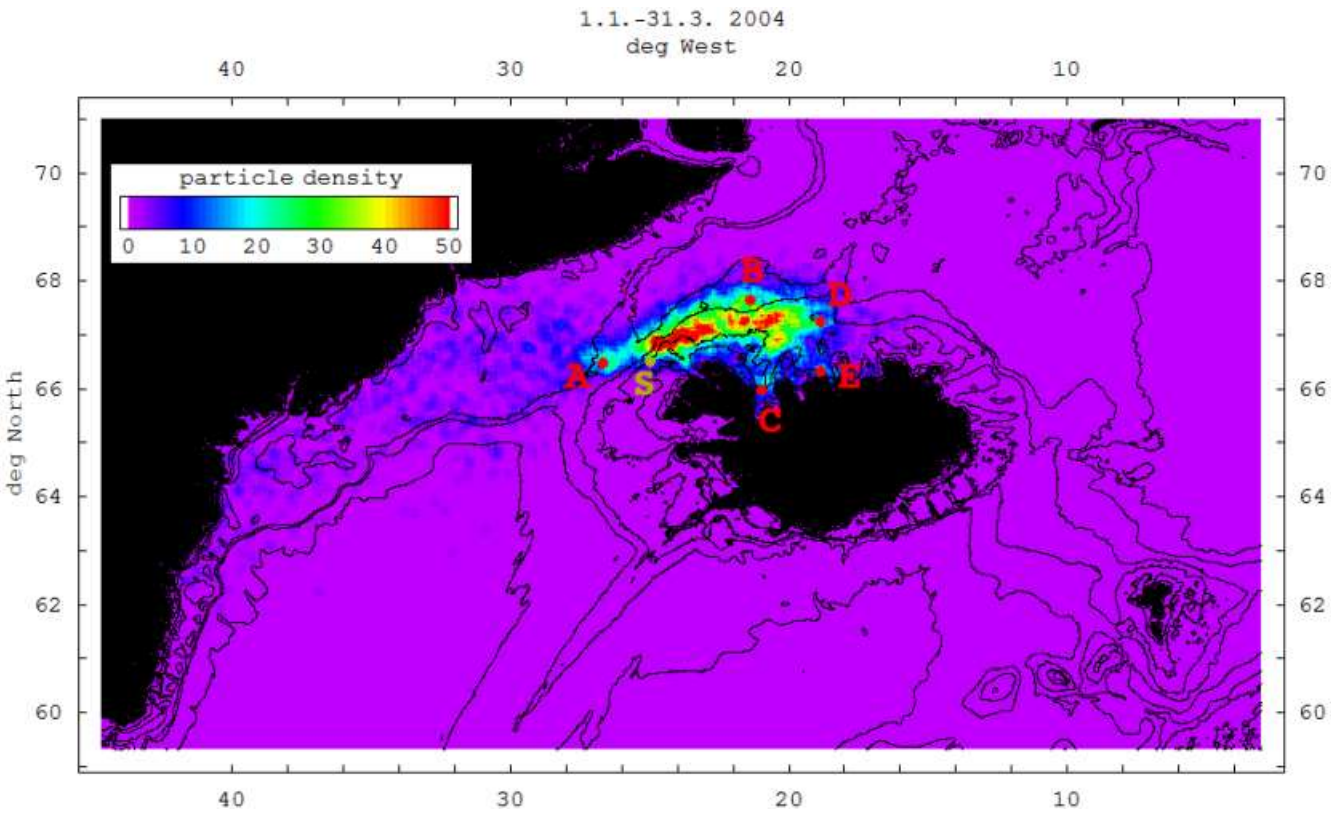
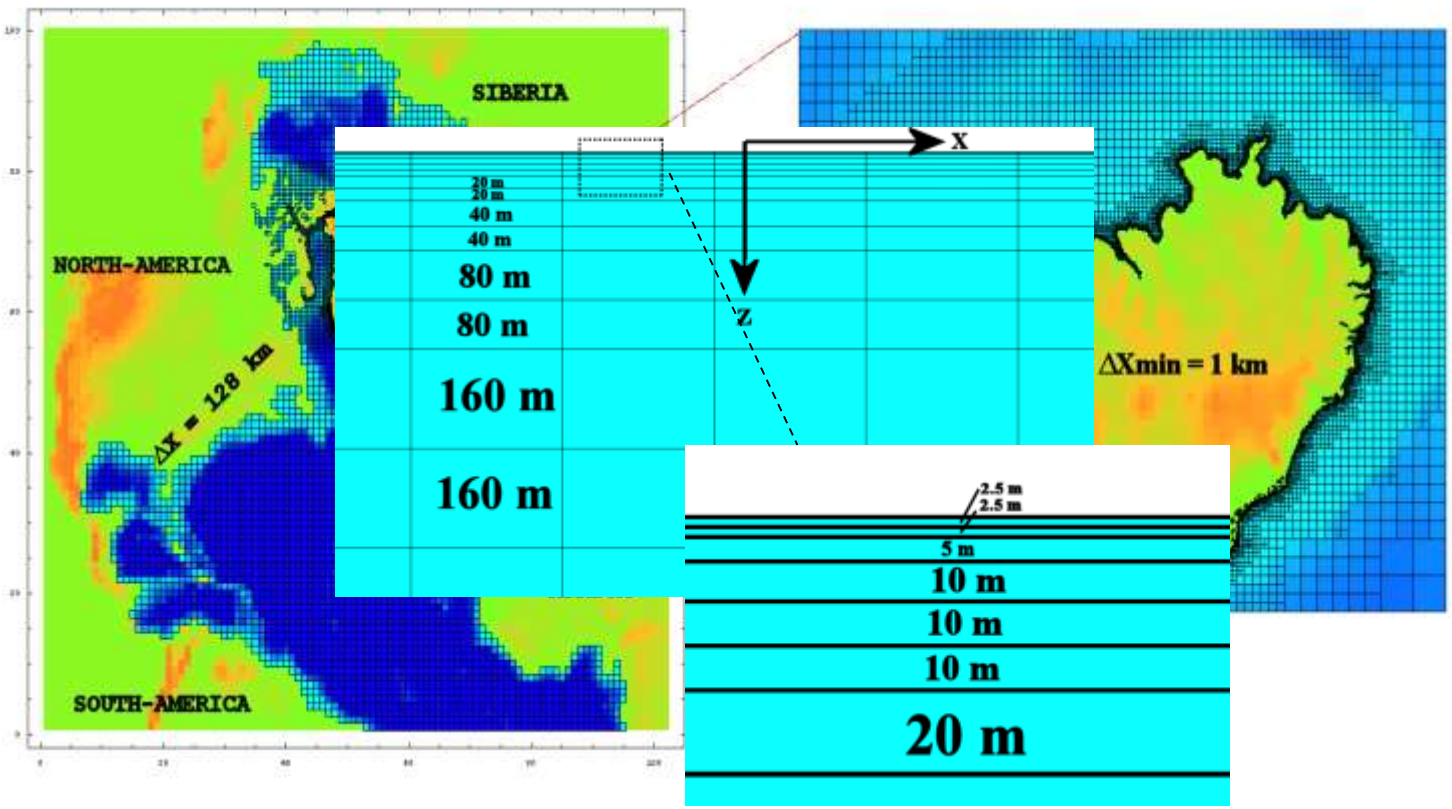
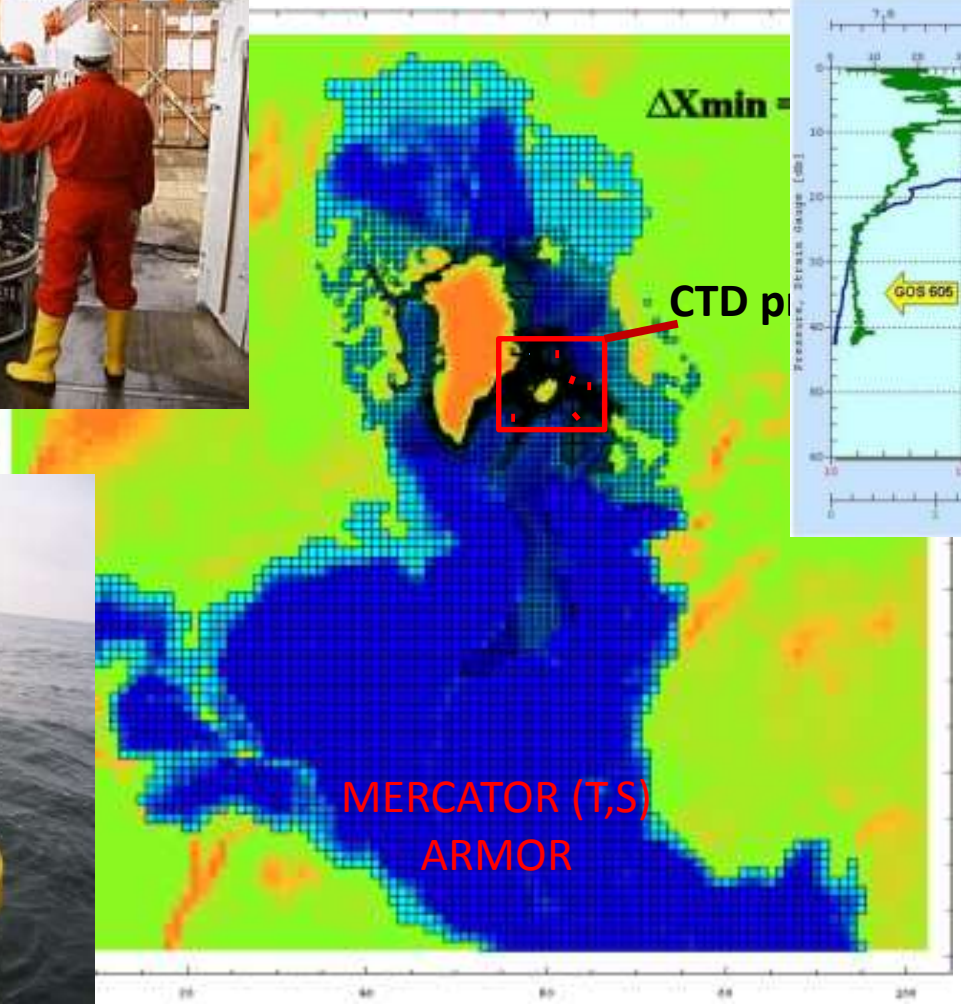


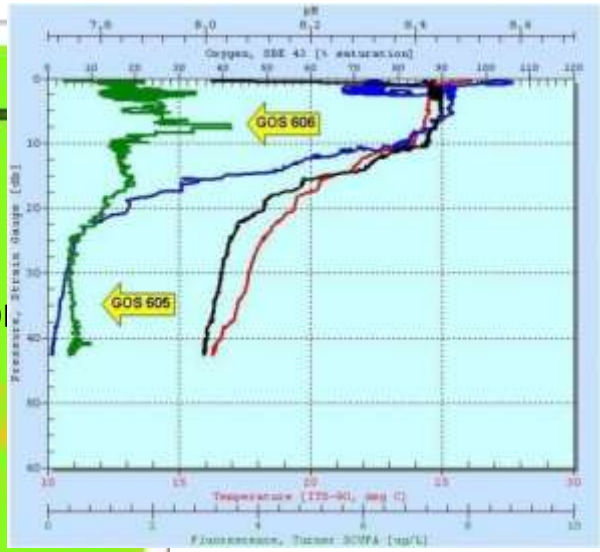
Fig. 6: Particle density at the end of the winter 2004 simulation. The point denoted with “S” shows the source position. The points “A”, “B”, “C”, “D”, and “E” denote the stations where time series were constructed.

Adaptive mesh refinement:



CTD data assimilation





GFS atmospheric forecasts

Aufzeichnung - Englisch - ... | Fotos: Die deutsche Manns... | SjoSpa

www.marsyn.is/sjospa/

Meistbesucht

CODE ocean model

- OCEAN ---------

sea surface elevation

temperature (1 m)
temperature (15 m)
temperature (50 m)

salinity (1 m)
salinity (15 m)
salinity (50 m)

current (1 m)
hourly
current (15 m)
current (50 m)

-SEA STATE ------
significant wave height

- ECOSYSTEM ------
nitrate
silicate
phosphate
flagellates
diatoms
micro/meso zooplankton
macro zooplankton
fish
chlorophyll (sat image)

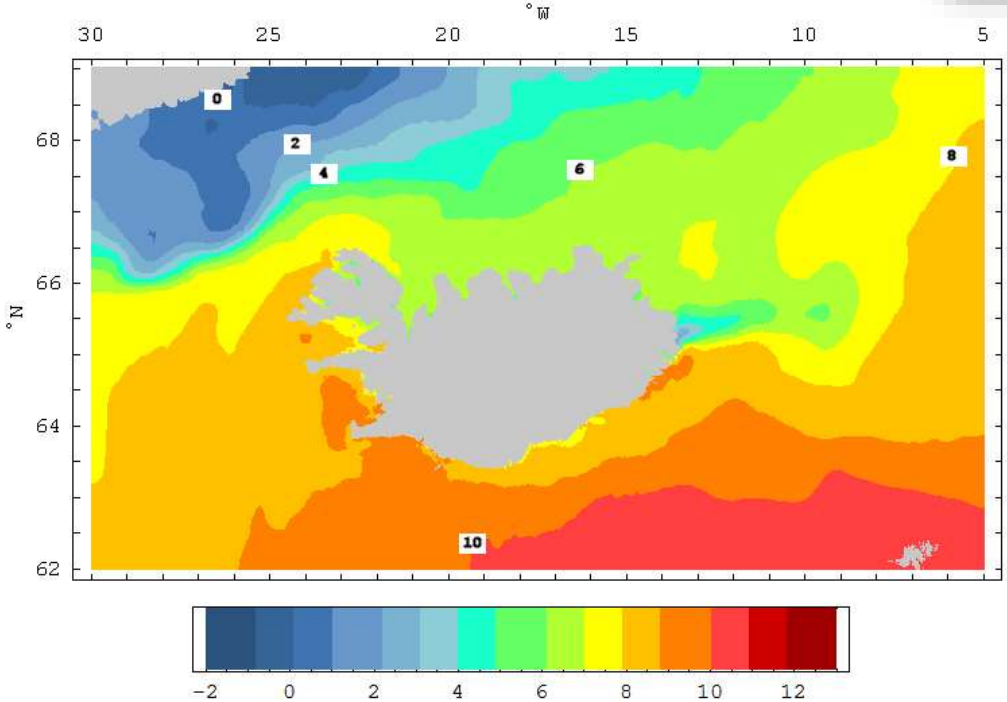
- ATMOSPHERE ----
air pressure
wind speed (m/s)
wind speed (Bft.)
air temperature
precipitation
cloud cover

Icelandic Waters | southern Faxaflói | south-west | Breiðafjörður | north-west | north | north-east | south-east | south

marsýn

CODE 000 hour forecast Valid: Fri 09.10.2015

temperature (depth = 1 m) [°C]



Previous | Animate | Next

Aufzeichnung - Englisch - ... | Fotos: Die deutsche Manns... | SjoSpa

www.marsyn.is/sjospa/

the incredible hulk, comic

Meistbesucht

CODE ocean model

- OCEAN ---------

sea surface elevation

temperature (1 m)
temperature (15 m)
temperature (50 m)

salinity (1 m)
salinity (15 m)
salinity (50 m)

current (1 m)
hourly
current (15 m)
current (50 m)

-SEA STATE ------
significant wave height

- ECOSYSTEM ------
nitrate
silicate
phosphate
flagellates
diatoms
micro/meso zooplankton
macro zooplankton
fish
chlorophyll (sat image)

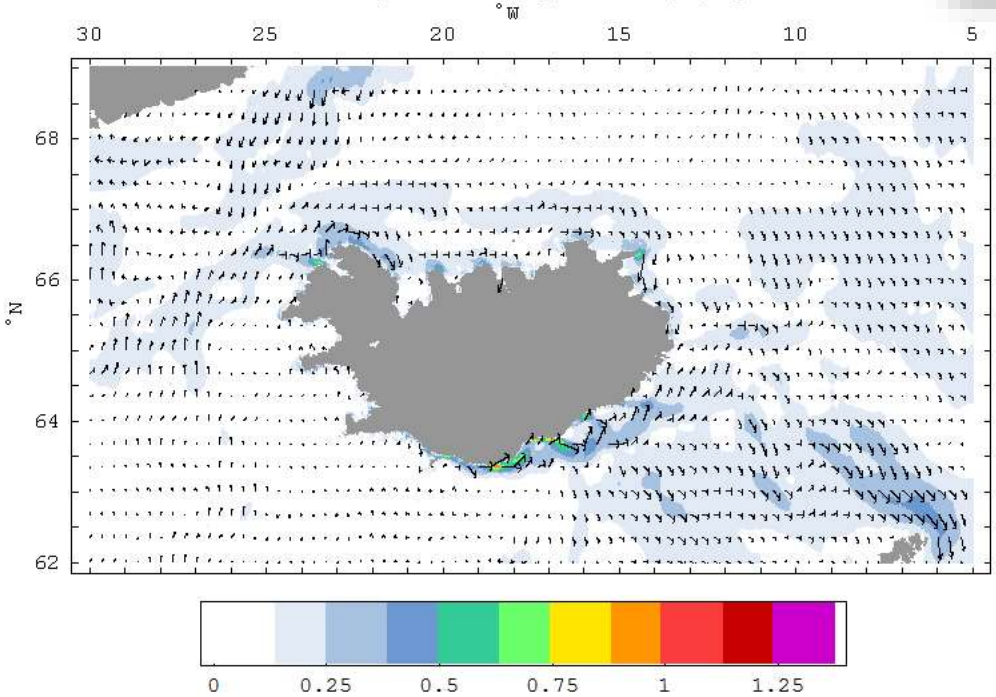
- ATMOSPHERE ----
air pressure
wind speed (m/s)
wind speed (Bft.)
air temperature
precipitation
cloud cover

Icelandic Waters | southern Faxaflói | south-west | Breiðafjörður | north-west | north | north-east | south-east | south

marsýn

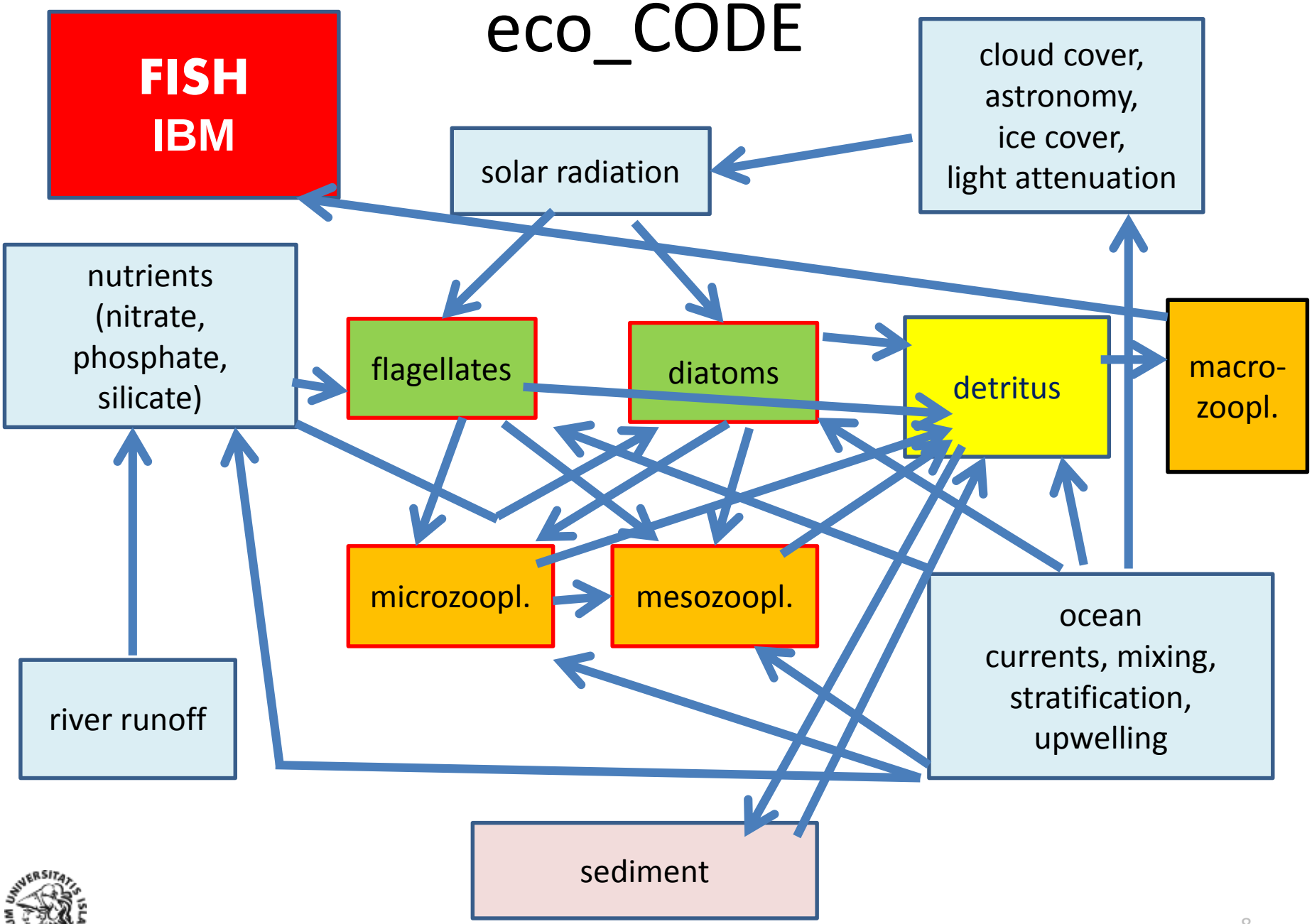
CODE 096 hour forecast Valid: Tue 13.10.2015

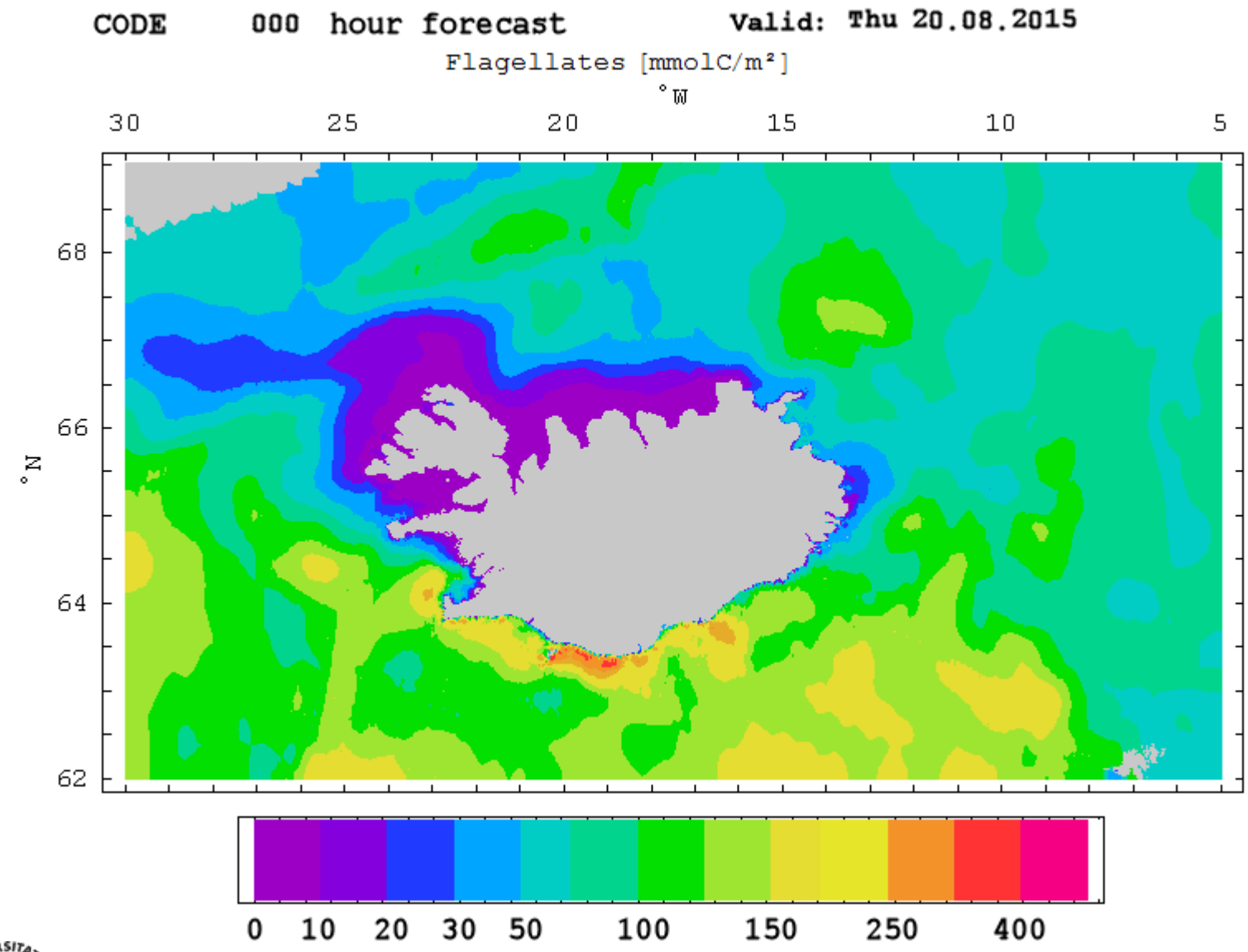
mean daily current (depth = 15 m) [kt]



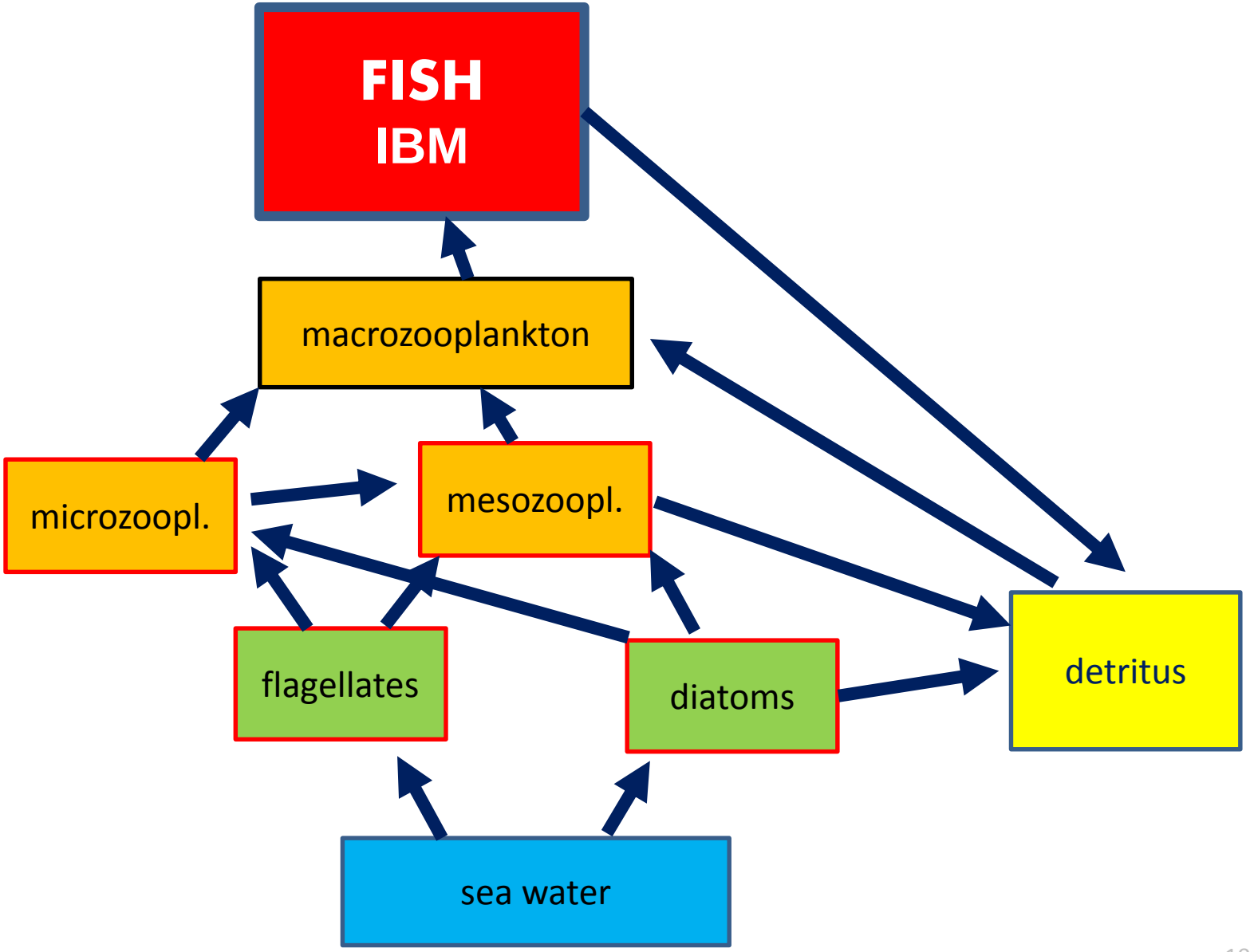
Previous | Animate | Next

eco_CODE


FISH
IBM
solar radiation
cloud cover,
astronomy,
ice cover,
light attenuation
nutrients
(nitrate,
phosphate,
silicate)
flagellates
diatoms
detritus
macro-
zoopl.
microzoopl.
mesozoopl.
ocean
currents, mixing,
stratification,
upwelling
river runoff
sediment


CODE 000 hour forecast
Valid: Thu 20.08.2015
Flagellates [mmolC/m²]
°W
30
25
20
15
10
5
68
66
64
62
°N
0
10
20
30
50
100
150
250
400

Carbon fluxes



carbon/pollutant fluxes

temp. change of diatom carbon density Ph_1 [mmolC/m³]

$$\frac{\partial Ph_1}{\partial t} = ADV_{Ph_1} + DIF_{Ph_1} + \sigma_1\ \Phi_1\ Ph_1 - m_1\ Ph_1 - graz_{11}\ Zo_1 - graz_{21}\ Zo_2 - graz_{31}\ Zo_3$$

RN [molX/molC] pollutant/carbon ratio:

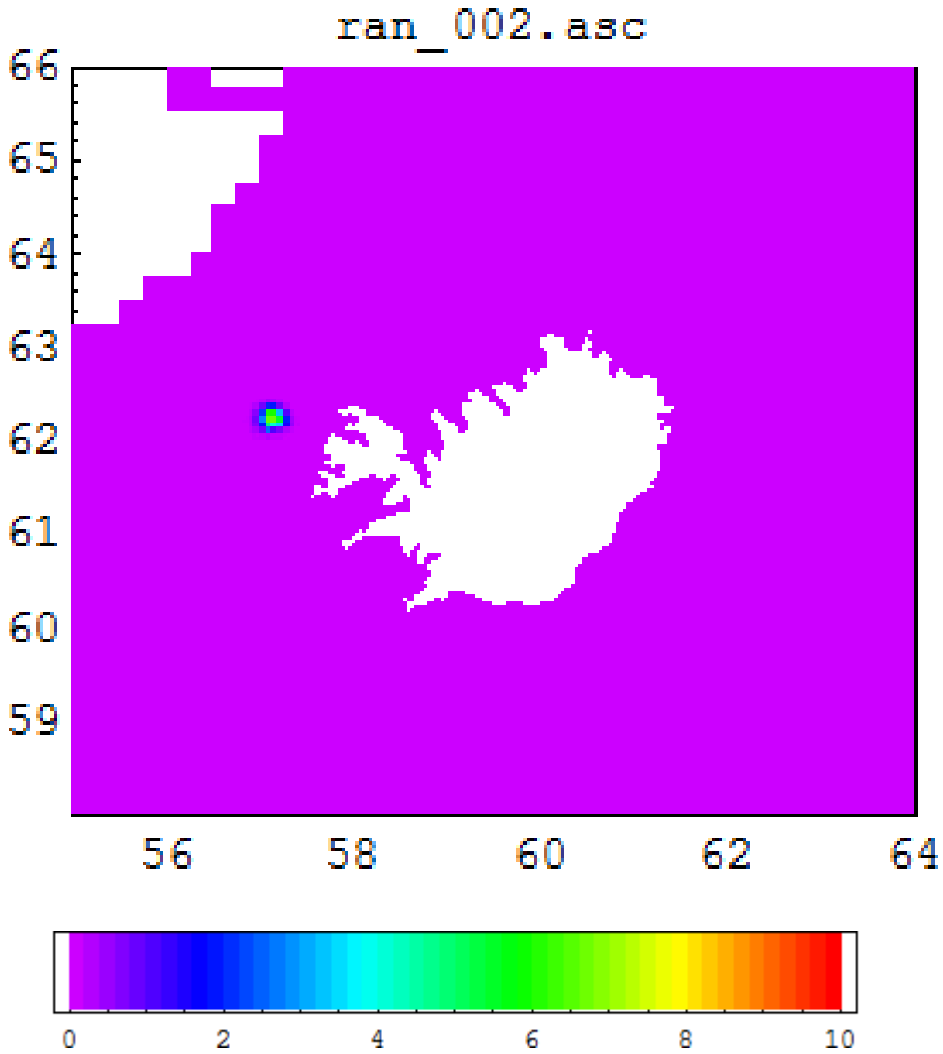
$$\frac{\partial RN}{\partial t} = ADV_{RN} + DIF_{RN} + Q$$

Ph_1^{RN} [mmolX/m³] sea water pollution by diatoms

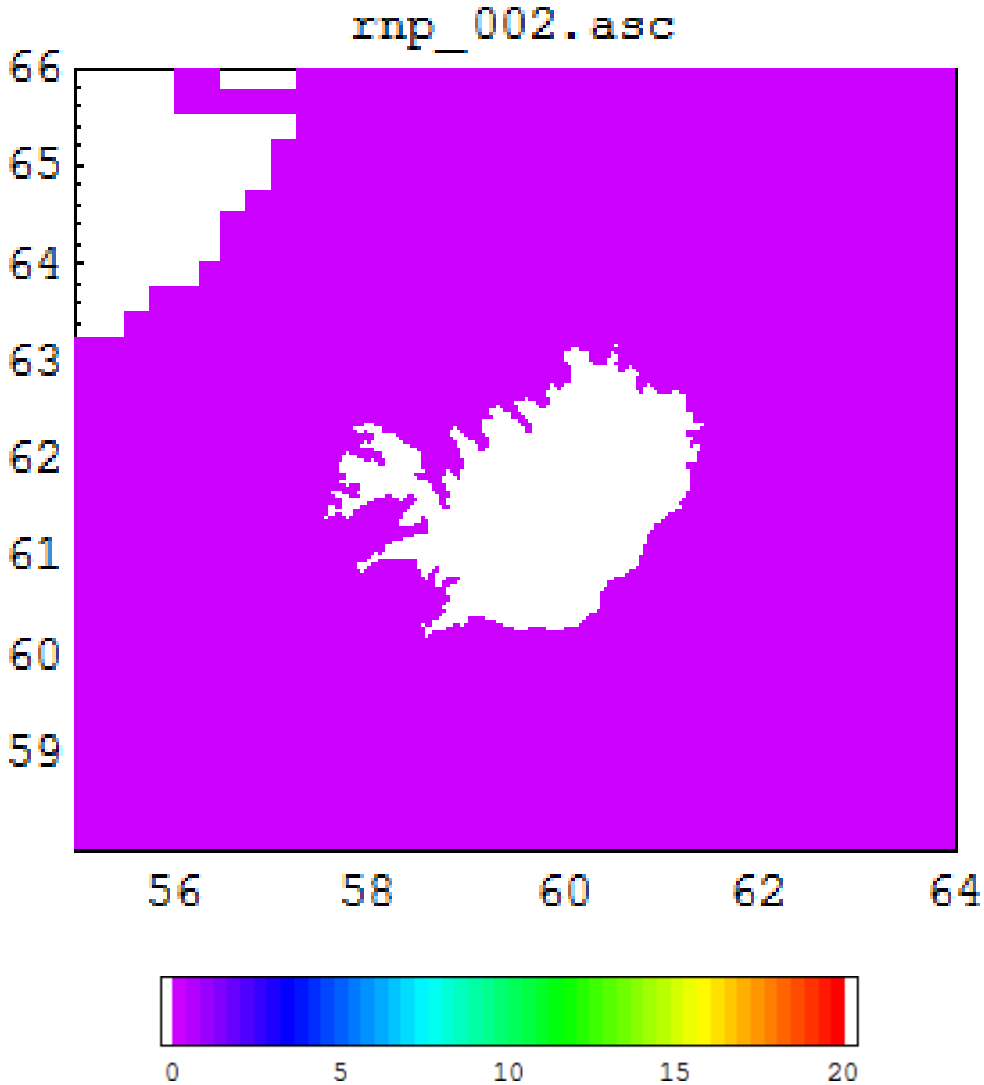
$$\frac{\partial Ph_1^{RN}}{\partial t} = ADV_{Ph_1^{RN}} + DIF_{Ph_1^{RN}} + \left(\sigma_1\ \Phi_1\ Ph_1\right) RN - m_1\ Ph_1^{RN} - \left(graz_{11}\ Zo_1 - graz_{21}\ Zo_2 - graz_{31}\ Zo_3\right) \frac{Ph_1^{RN}}{Ph_1}$$

$$\frac{\partial Zo_1^{RN}}{\partial t} = ADV_{Zo_1^{RN}} + DIF_{Zo_1^{RN}} + \left(graz_{11}\ Zo_1\right) \frac{Ph_1^{RN}}{Ph_1} + \ldots$$

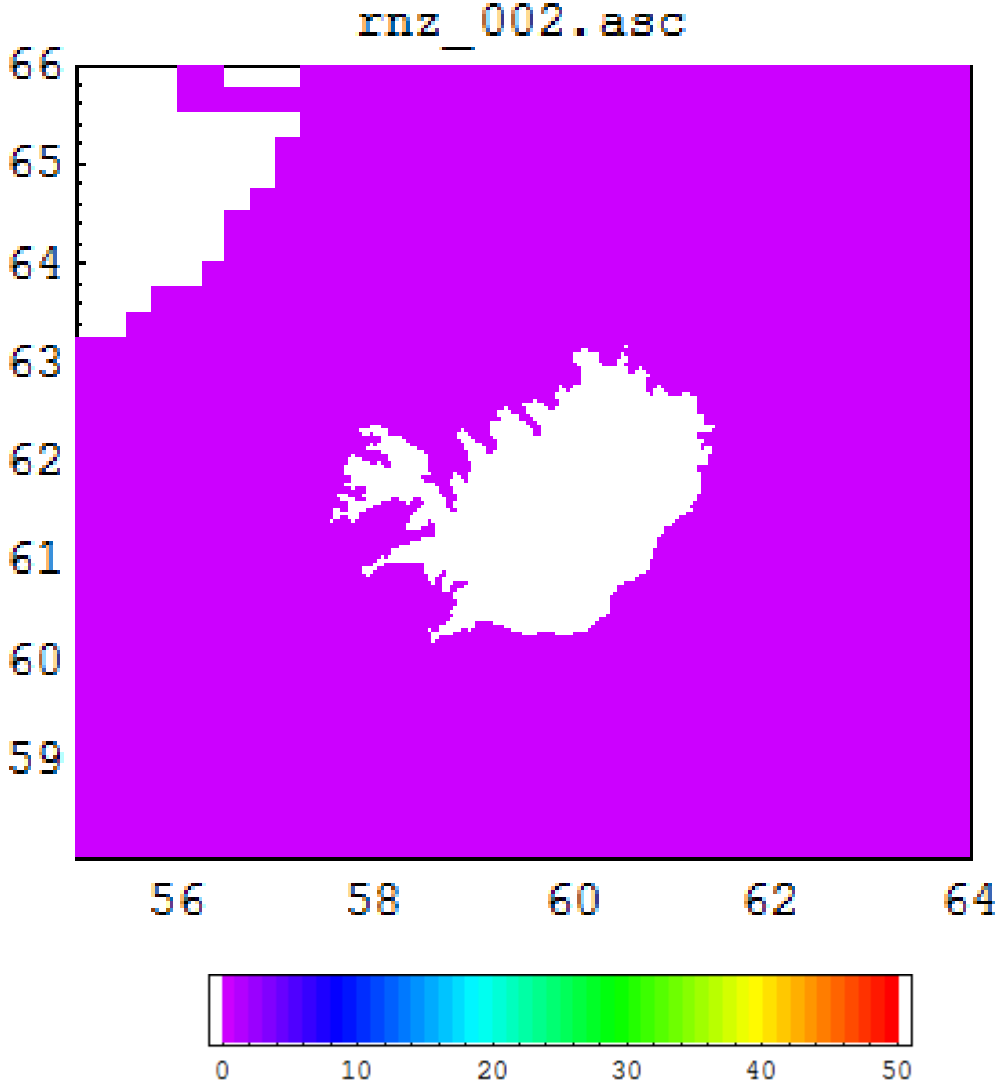
pollutant dispersion (sea water) [molX/molC]



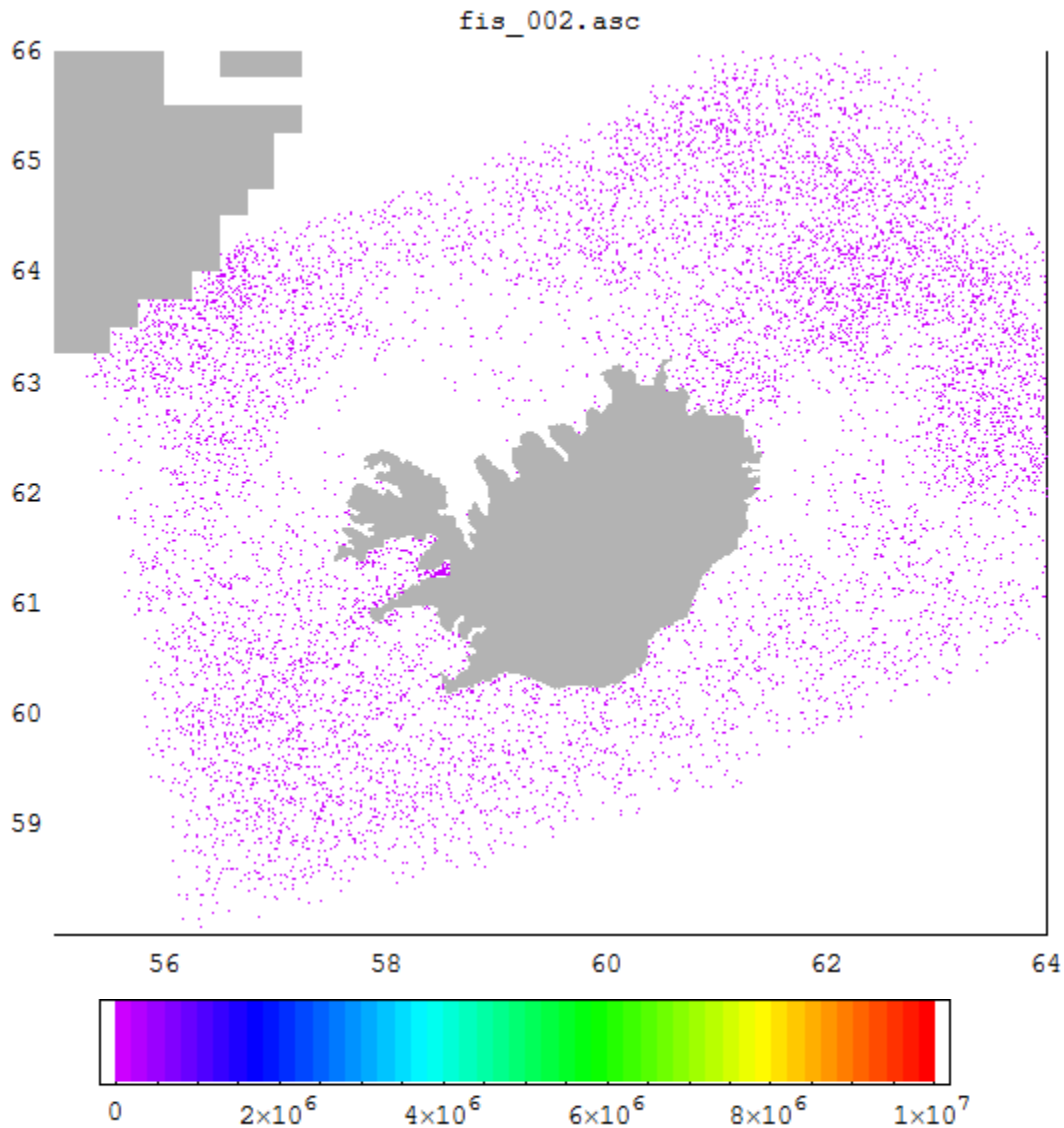
phytoplankton contamination [mmolX/m³]



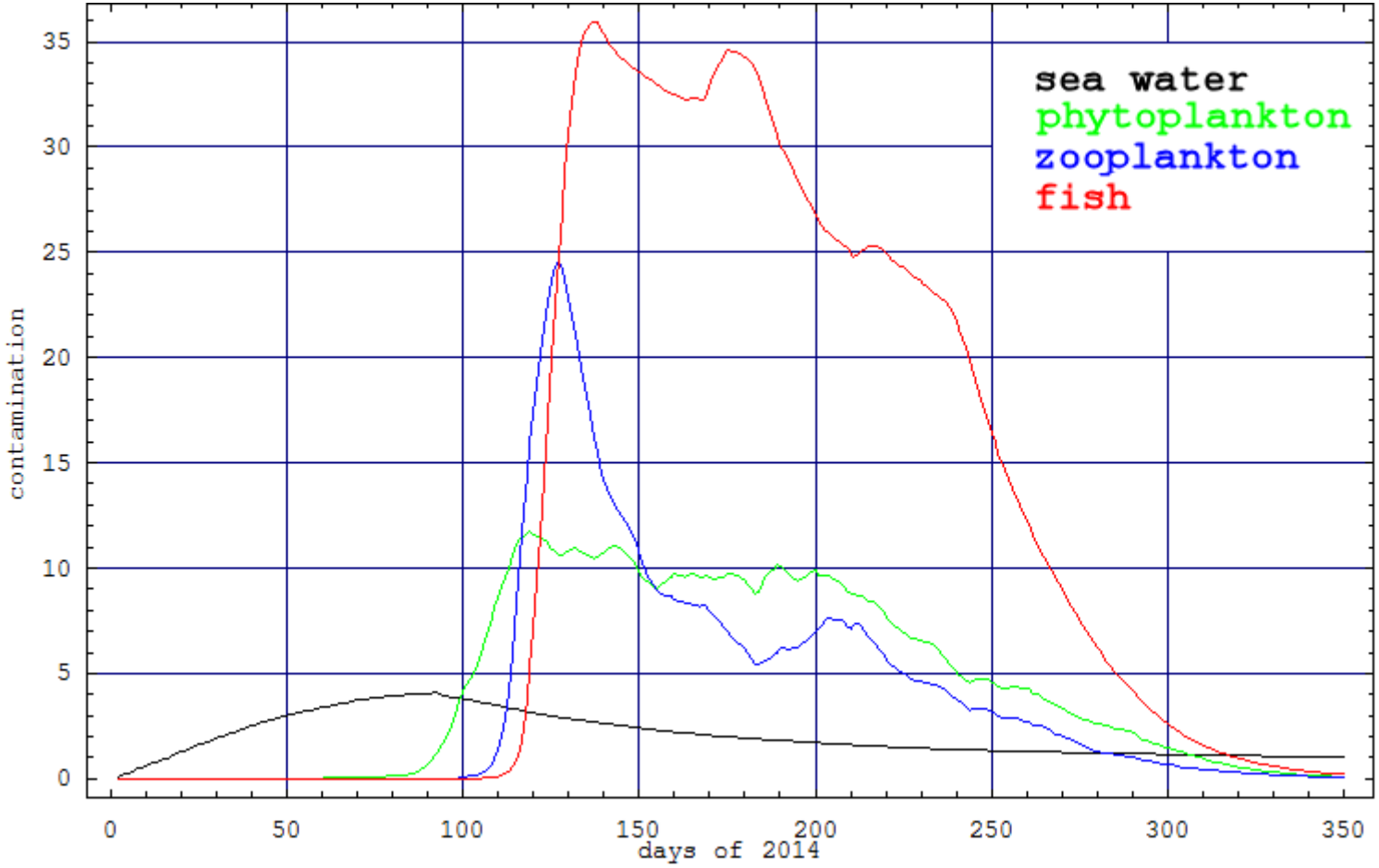
zooplankton contamination [mmolX/m³]



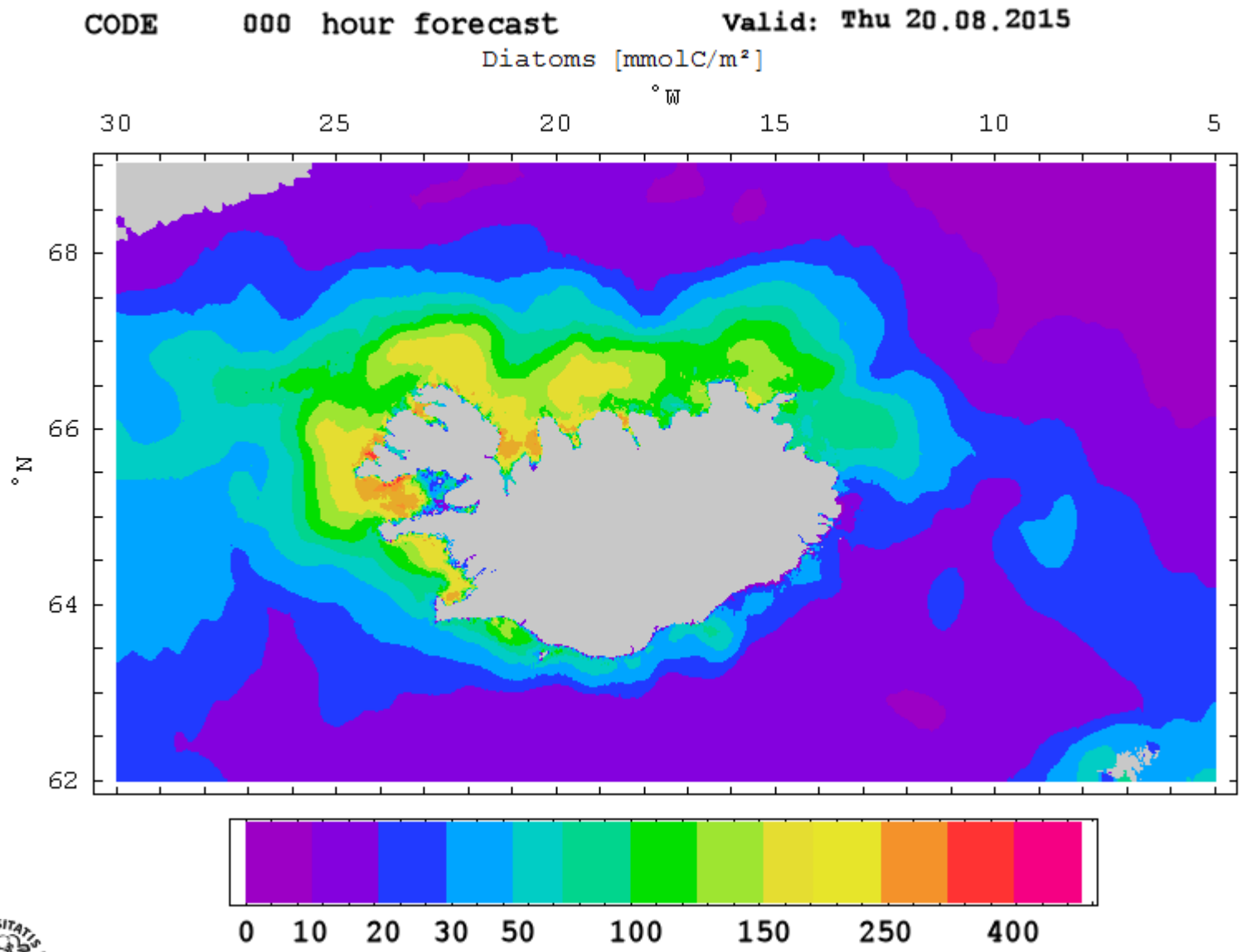
fish contamination [mmolX]

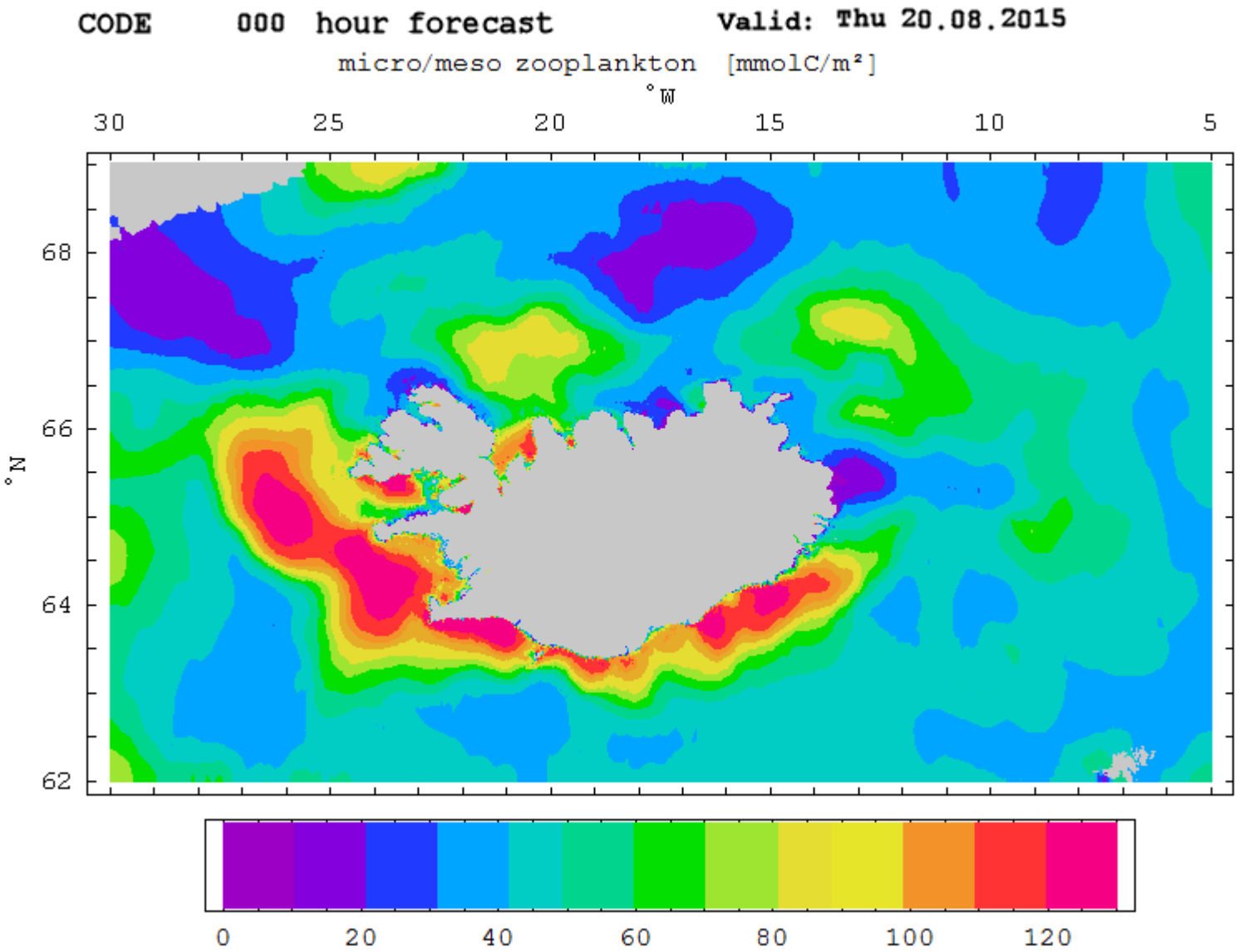


contamination development



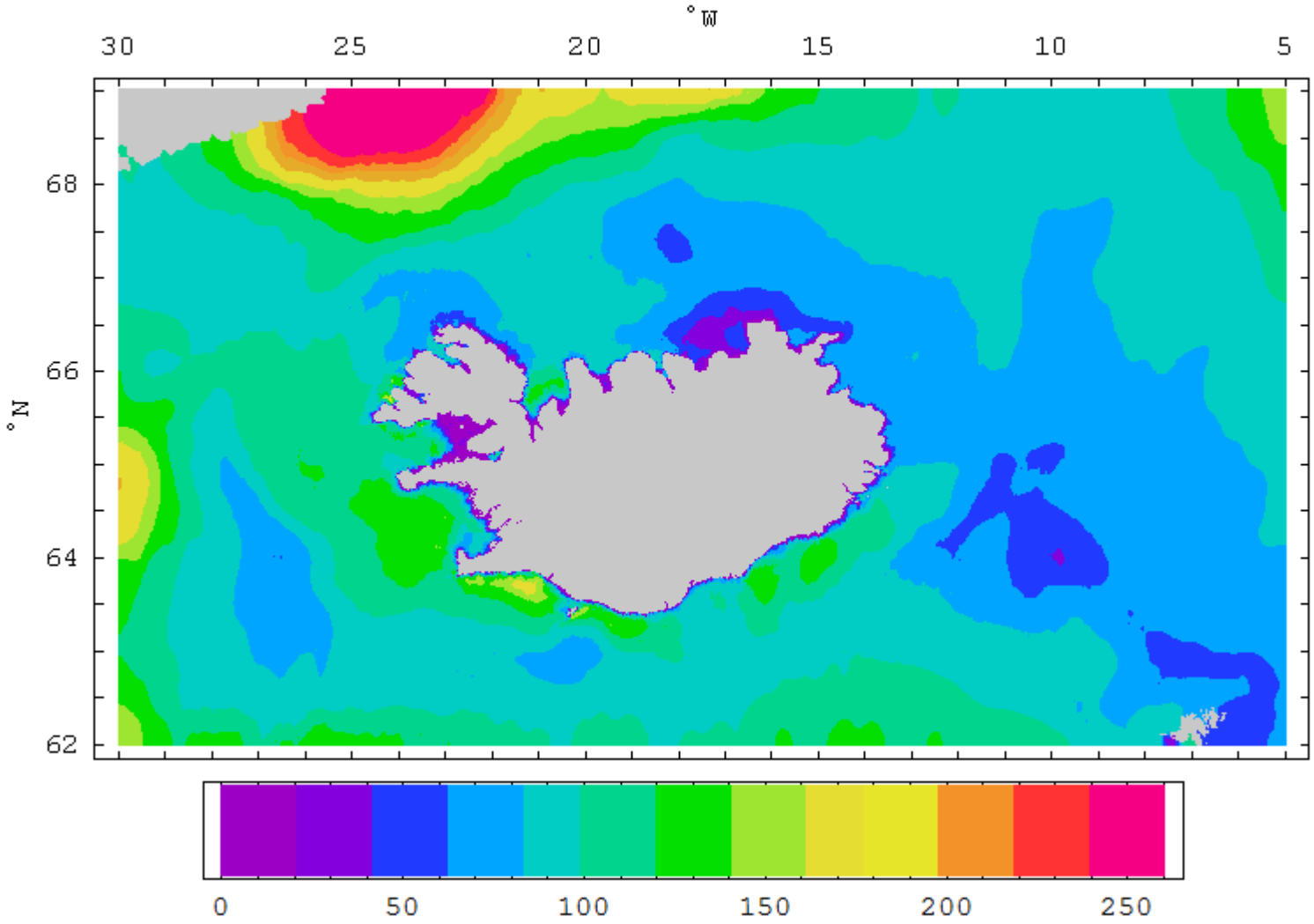
Thank you!


CODE 000 hour forecast
Valid: Thu 20.08.2015
Diatoms [mmolC/m²]
°W
30
25
20
15
10
5
68
66
64
62
°N
0
10
20
30
50
100
150
250
400


CODE 000 hour forecast
Valid: Thu 20.08.2015
micro/meso zooplankton [mmolC/m²]
°W
30
25
20
15
10
5
68
66
64
62
°N
0
20
40
60
80
100
120

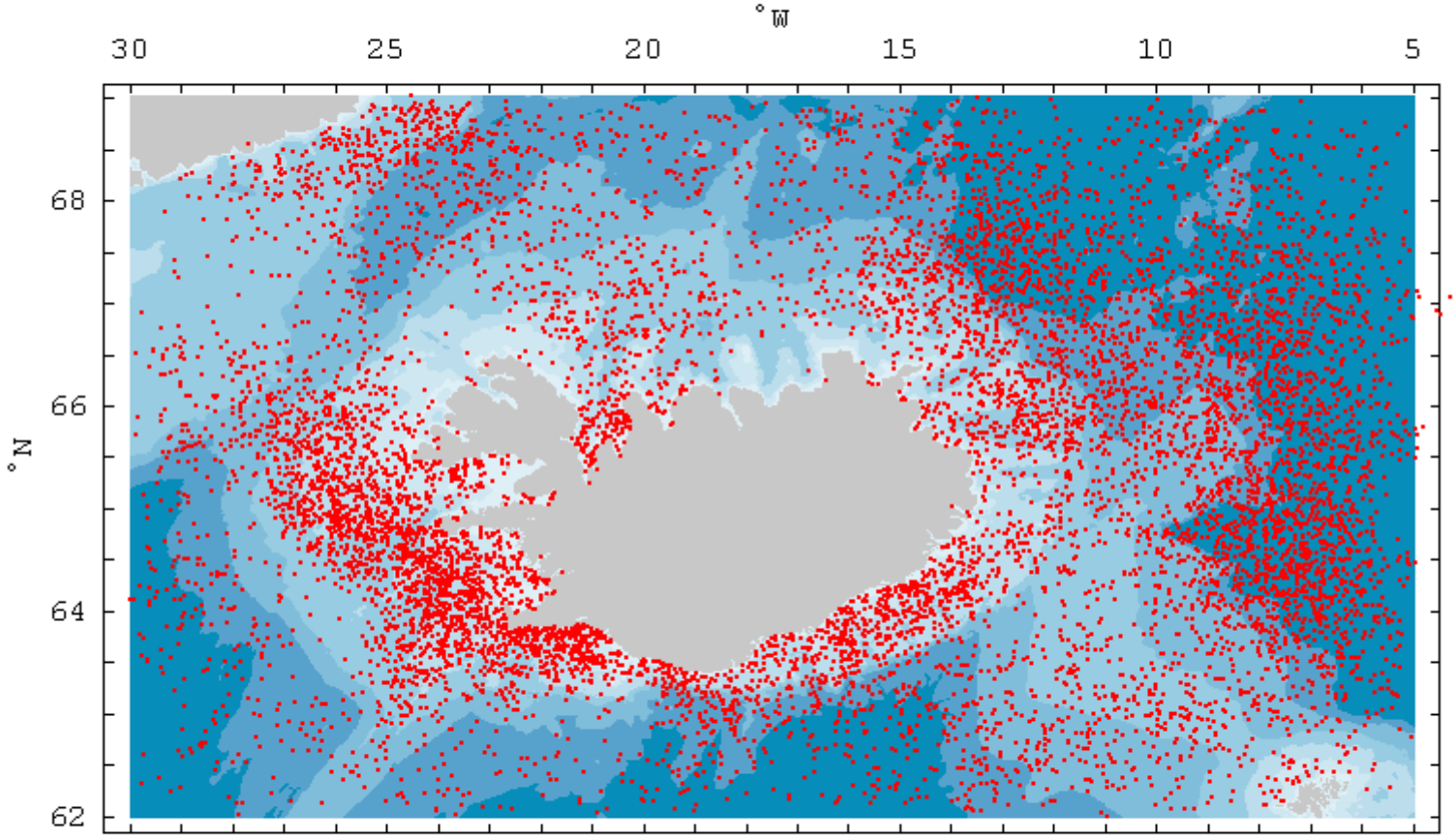
macro zooplankton [mmolC/m²]

CODE 000 hour forecast **Valid: Thu 20.08.2015**



virtual fish

CODE 000 hour forecast **Valid: Thu 20.08.2015**



CODE

***C**artesian coordinates **O**cean model with three-**D**imensional adaptive mesh refinement and primitive **E**quations*

primitive equations: $(u,v,w),\zeta,p,\rho,T,S$

$$\frac{du}{dt} = f\ v + \frac{\partial}{\partial x}\left(A_H\ \frac{\partial u}{\partial x}\right) + \frac{\partial}{\partial y}\left(A_H\ \frac{\partial u}{\partial y}\right) + \frac{\partial}{\partial z}\left(A_V\ \frac{\partial u}{\partial z}\right) - \frac{1}{\rho_0}\frac{\partial p}{\partial x} - \frac{\partial \Phi_T}{\partial x}$$

$$\frac{dv}{dt} = -f\ u + \frac{\partial}{\partial x}\left(A_H\ \frac{\partial v}{\partial x}\right) + \frac{\partial}{\partial y}\left(A_H\ \frac{\partial v}{\partial y}\right) + \frac{\partial}{\partial z}\left(A_V\ \frac{\partial v}{\partial z}\right) - \frac{1}{\rho_0}\frac{\partial p}{\partial y} - \frac{\partial \Phi_T}{\partial y}$$

$$w = -\int_{z'=-D}^{z'=z}\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right)dz'$$

$$\frac{\partial \zeta}{\partial t} = w(z=\zeta)$$

$$p = \int_{z'=z}^{z'=\zeta} \rho\ g\ dz' + p_{AIR}$$

$$\rho = \rho(S,T,p) \approx \rho(S,T,-\rho_0\ g\ z)$$

$$\frac{\partial T}{\partial t} = -u\frac{\partial T}{\partial x} - v\frac{\partial T}{\partial y} - w\left(\frac{\partial T}{\partial z} + \Gamma\right) + \frac{\partial}{\partial x}\left(K_{H,T}\ \frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_{H,T}\ \frac{\partial T}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_{V,T}\left(\frac{\partial T}{\partial z} + \Gamma\right)\right) + Q_T$$

$$\frac{\partial S}{\partial t} = -u\frac{\partial S}{\partial x} - v\frac{\partial S}{\partial y} - w\frac{\partial S}{\partial z} + \frac{\partial}{\partial x}\left(K_{H,S}\ \frac{\partial S}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_{H,S}\ \frac{\partial S}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_{V,S}\ \frac{\partial S}{\partial z}\right) + Q_S$$

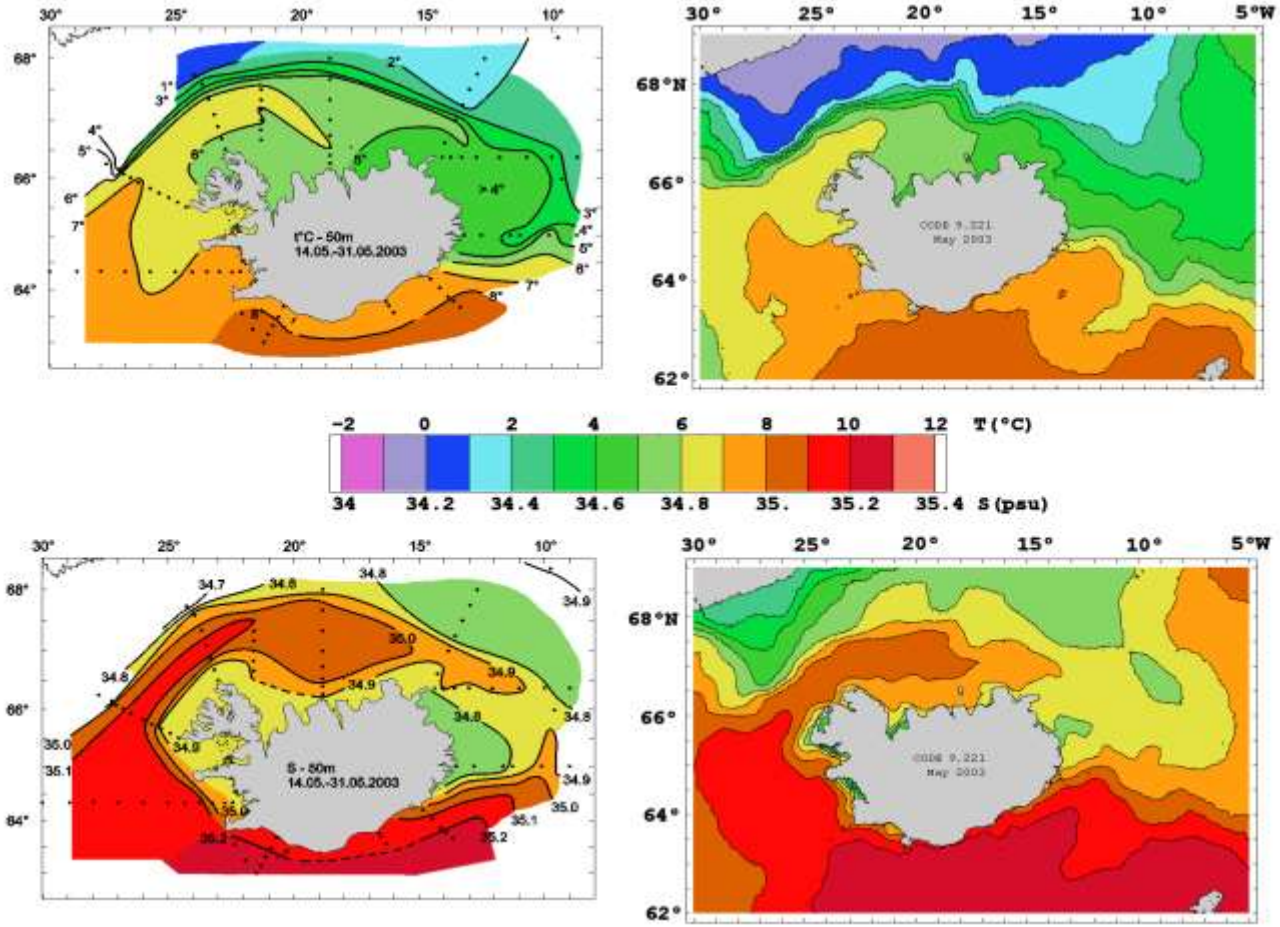
Numercial methods:

- Finite differences
- Implicit schemes for *U,V,T,S* advection, diffusion, semi-implicit for the sea surface elevation
- Advection with van Leer flux limiter
- Smagorinsky, Kochergin turbulence closure
- Spatial discretisation with adaptive mesh refinement
- CTD data assimilation
- Parallelization with OpenMP
- 978402 grid cells, Δt = 300 s

Intel Xeon 3.33 GHz – 12 core CPU, 92 hours/yr

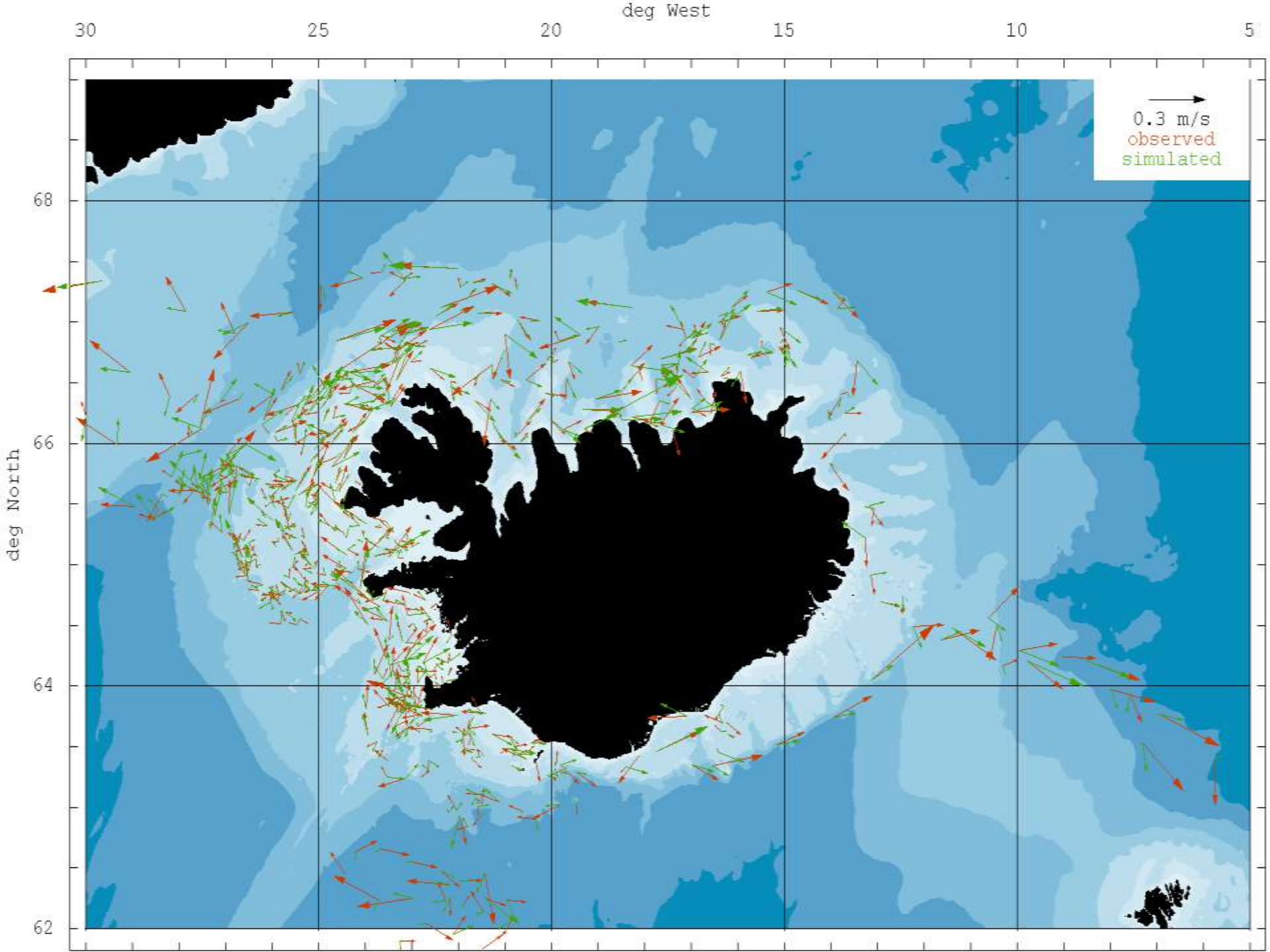
Validation May 2003

observed (hafro.is) **simulated**



T

S


deg West
30
25
20
15
10
5
deg North
68
66
64
62
0.3 m/s
observed
simulated