A full cycle anchovy & sardine model for the N. Aegean Sea

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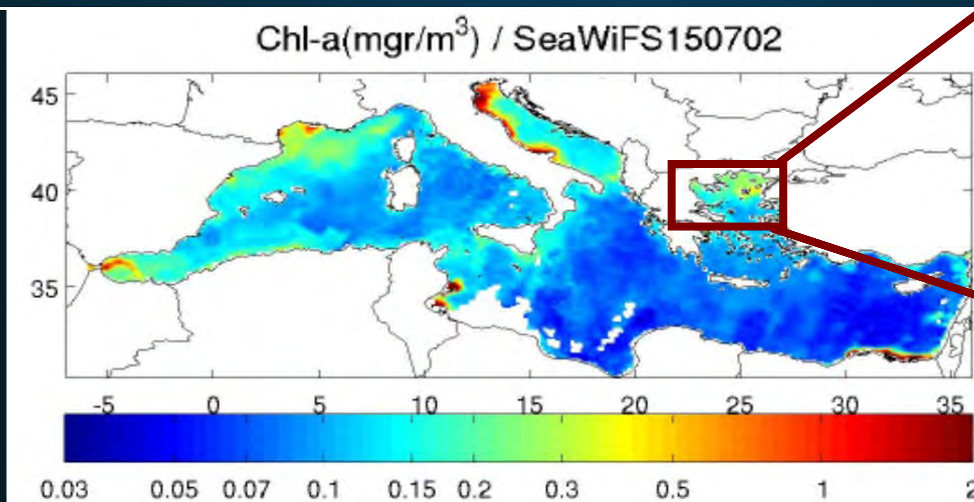
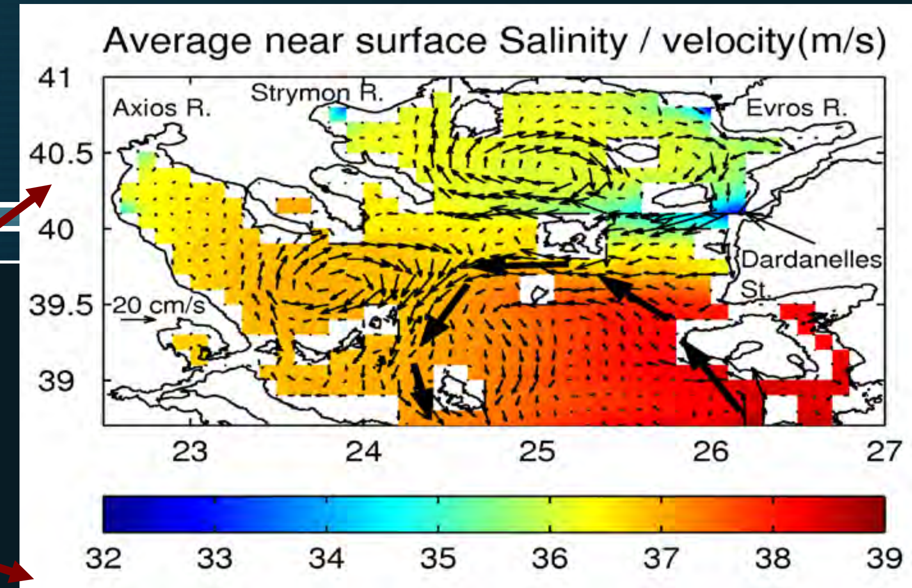
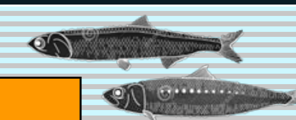
N. Aegean supports the main anchovy sardine stocks in the Mediterranean





N. Aegean increased productivity

- river inputs
- Black Sea Water inflow



Suite of Models

POSEIDON operational atmospheric model

Hydrodynamic model POM (Blumberg and Mellor, 1983)

Biogeochemical model ERSEM (Baretta et al., 1995)

LTL model

Organic matter, nutrients

Currents, Temperature, Zooplankton

Anchovy & Sardine model

Bioenergetic model
Population model
movement model

Bioenergetics

Wisconsin bioenergetics framework

$$\frac{dW}{W \cdot dt} = \left[C - (R + S + F + E + P)\right] \cdot \frac{CAL_z}{CAL_f}$$

Change of weight

Consumption

Respiration

Specific dynamic action

Egestion

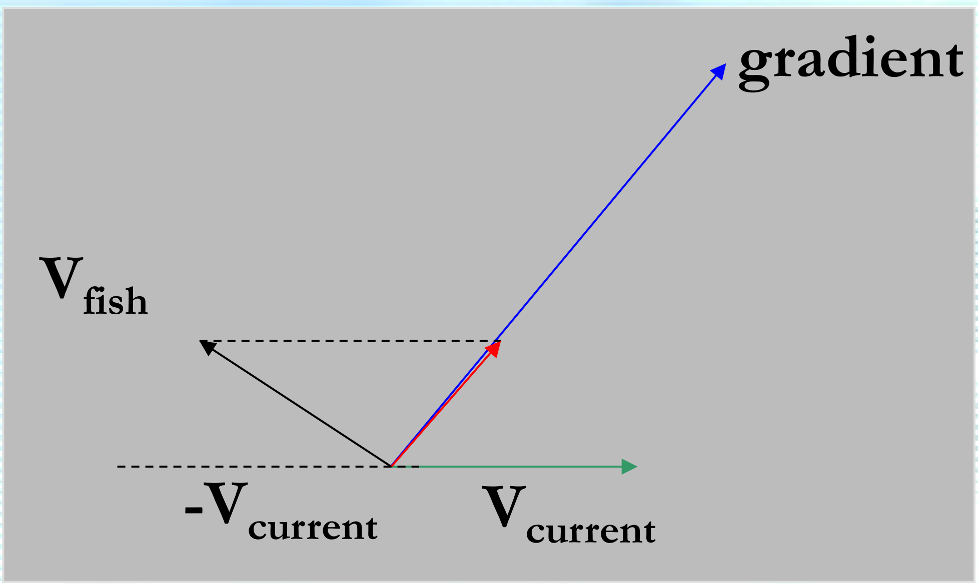
Excretion

Egg production

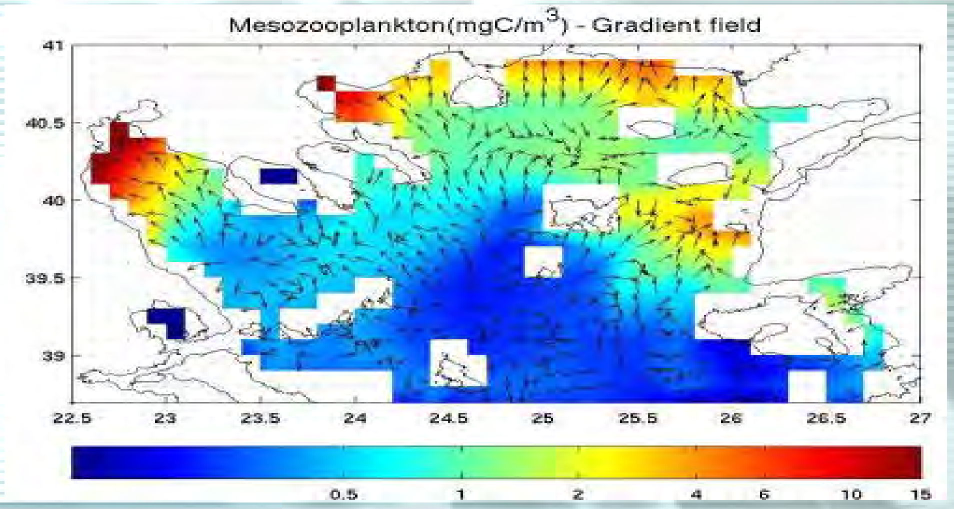
Movement

Restricted area search

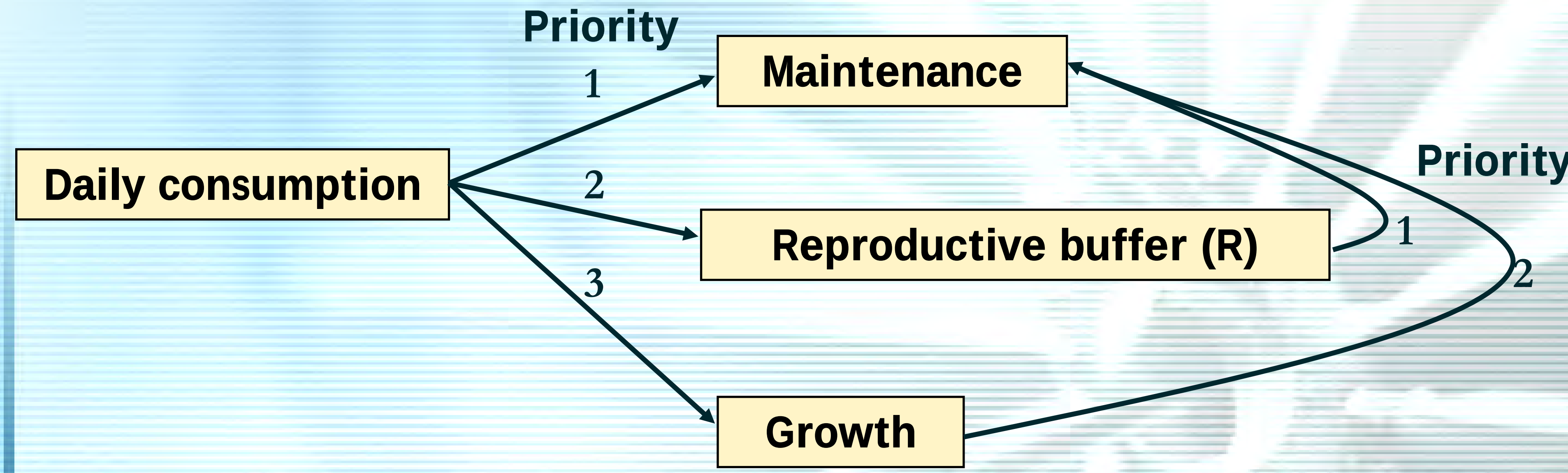
$$\vec{V}_{gradient} = \vec{V}_{current} + \vec{V}_{fish} + \vec{S}_{stochastic}$$



Gradient: per capita food availability

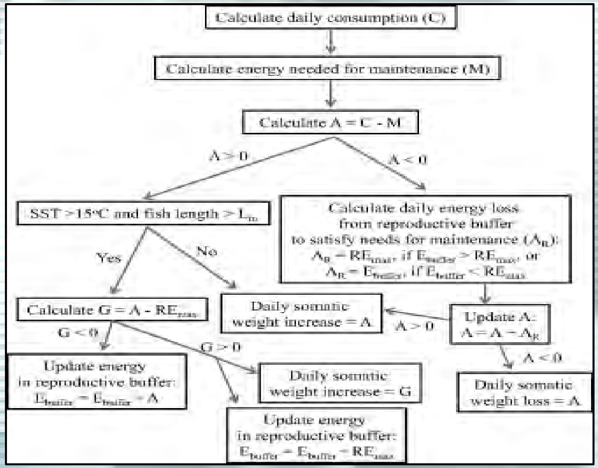


Dynamic Egg production

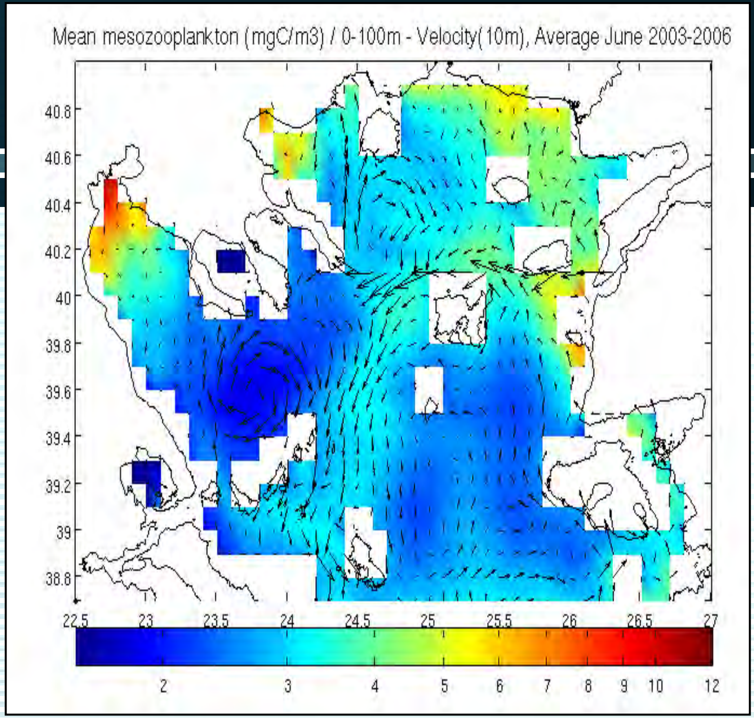


Anchovy: Energy channeled to the reproductive buffer during the spawning period (income breeder)

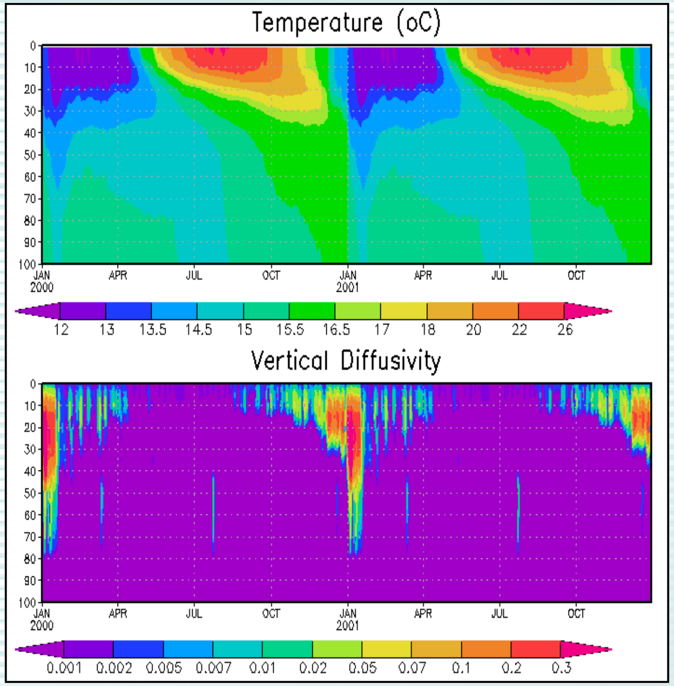
Sardine: Energy channeled to the reproductive buffer during the entire year (capital breeder)

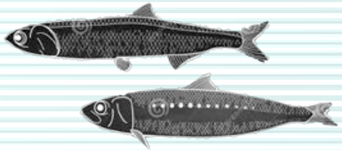


For the needs of the 1D simulations, the following were used:



- **Forcing**
- Temperature and vertical diffusivity daily average profiles from 3-D model (year 2003)
- Initial Conditions for biogeochemical variables from 3-D model average profiles
- Nutrient (NO_3, PO_4) input at surface (~rivers, BSW)
- **Anchovy Sardine model**
- Dynamic larvae mortality (~larvae/(larvae+K)) to maintain population stability
- **Two-way coupling**
- Fluxes (consumption of zooplankton & return of fish by-products)
- Normalize to the 1D water column dividing the fluxes from entire anchovy stock by continental shelf area





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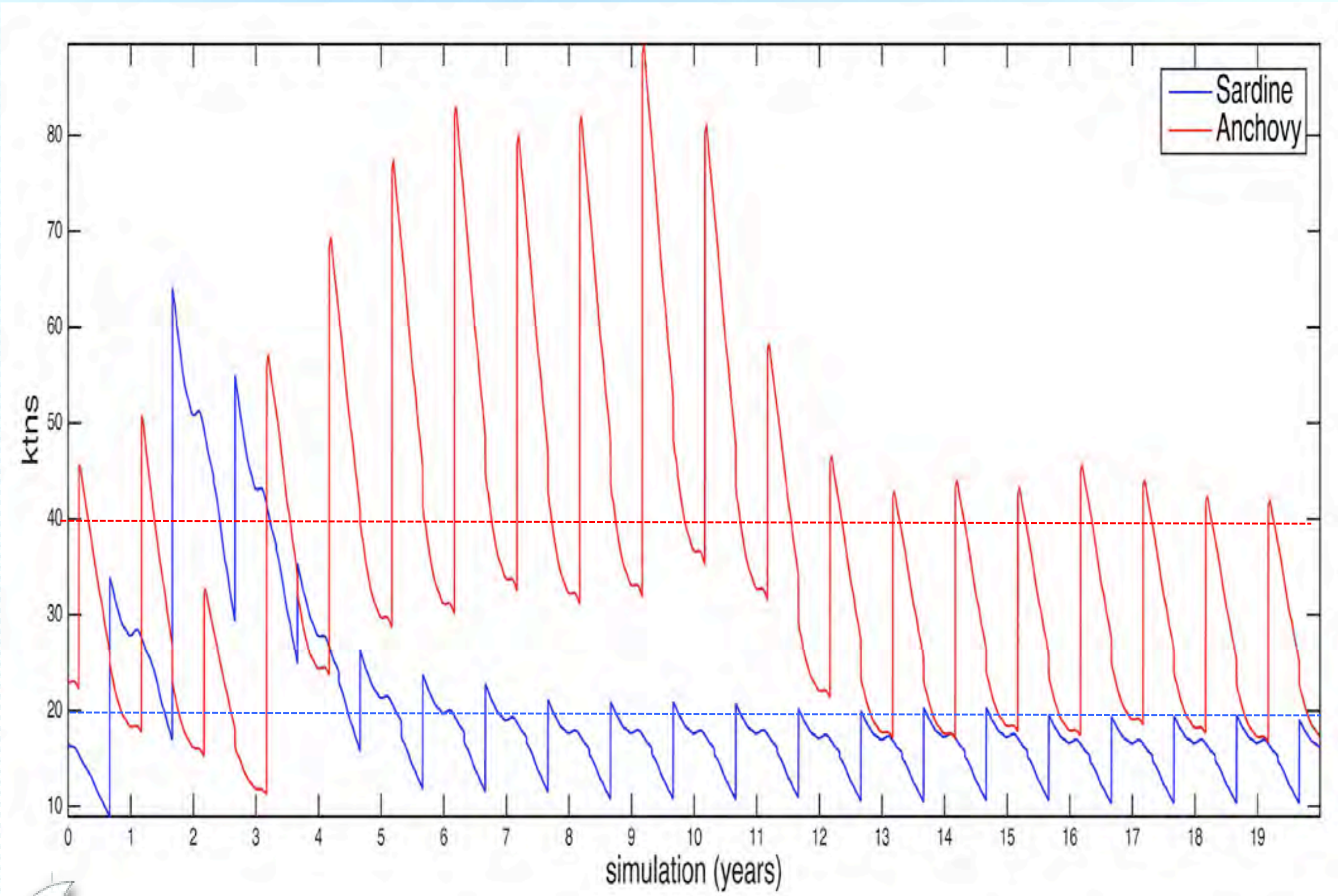
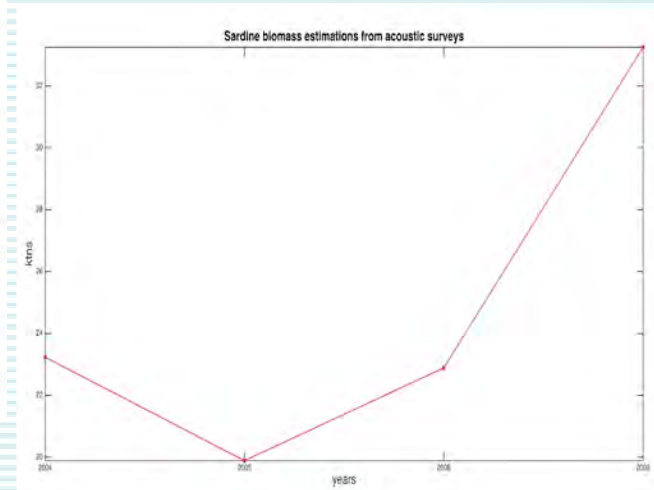
1D model

Anchovy and Sardine biomass evolution.
Run 20 years climatology perpetually

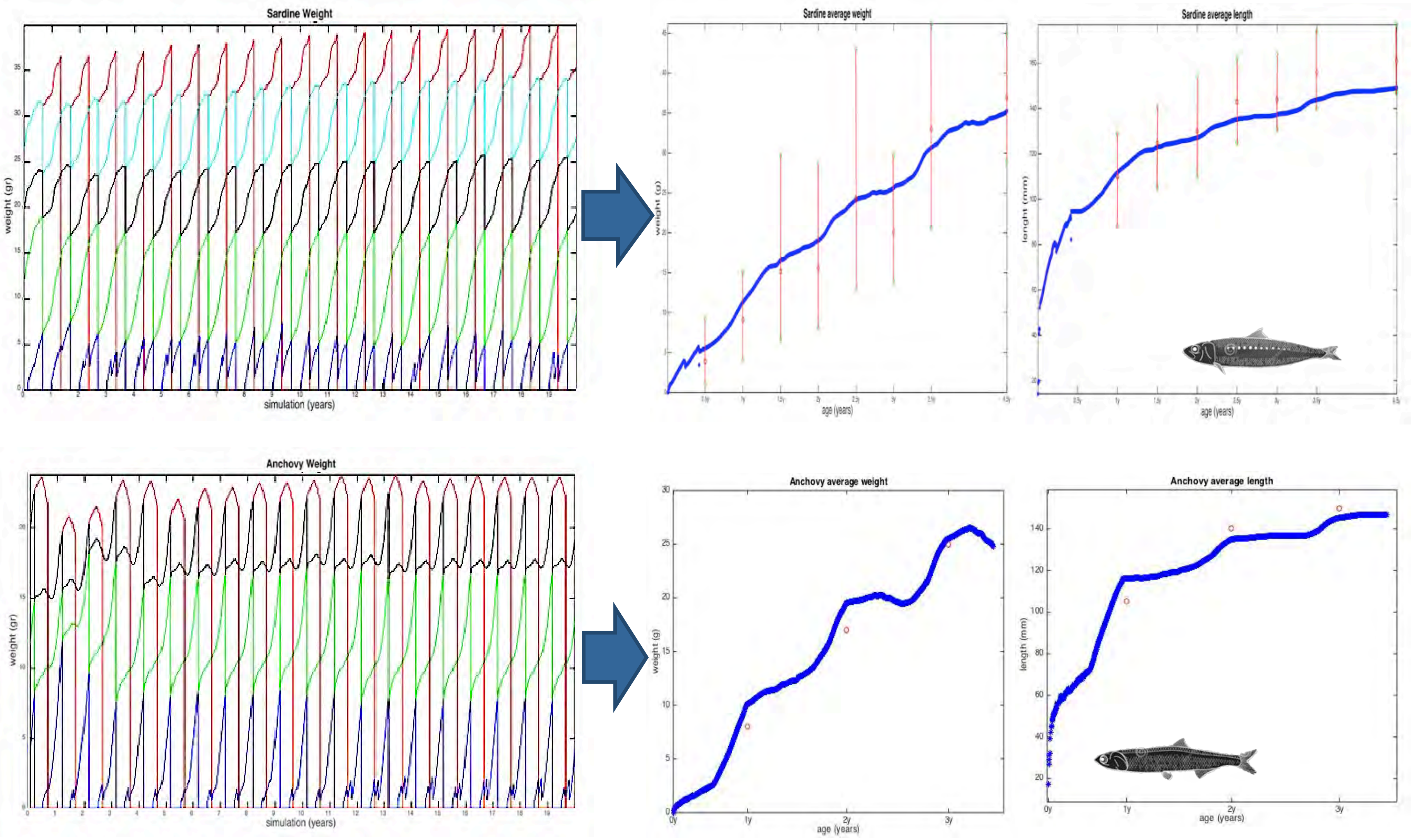


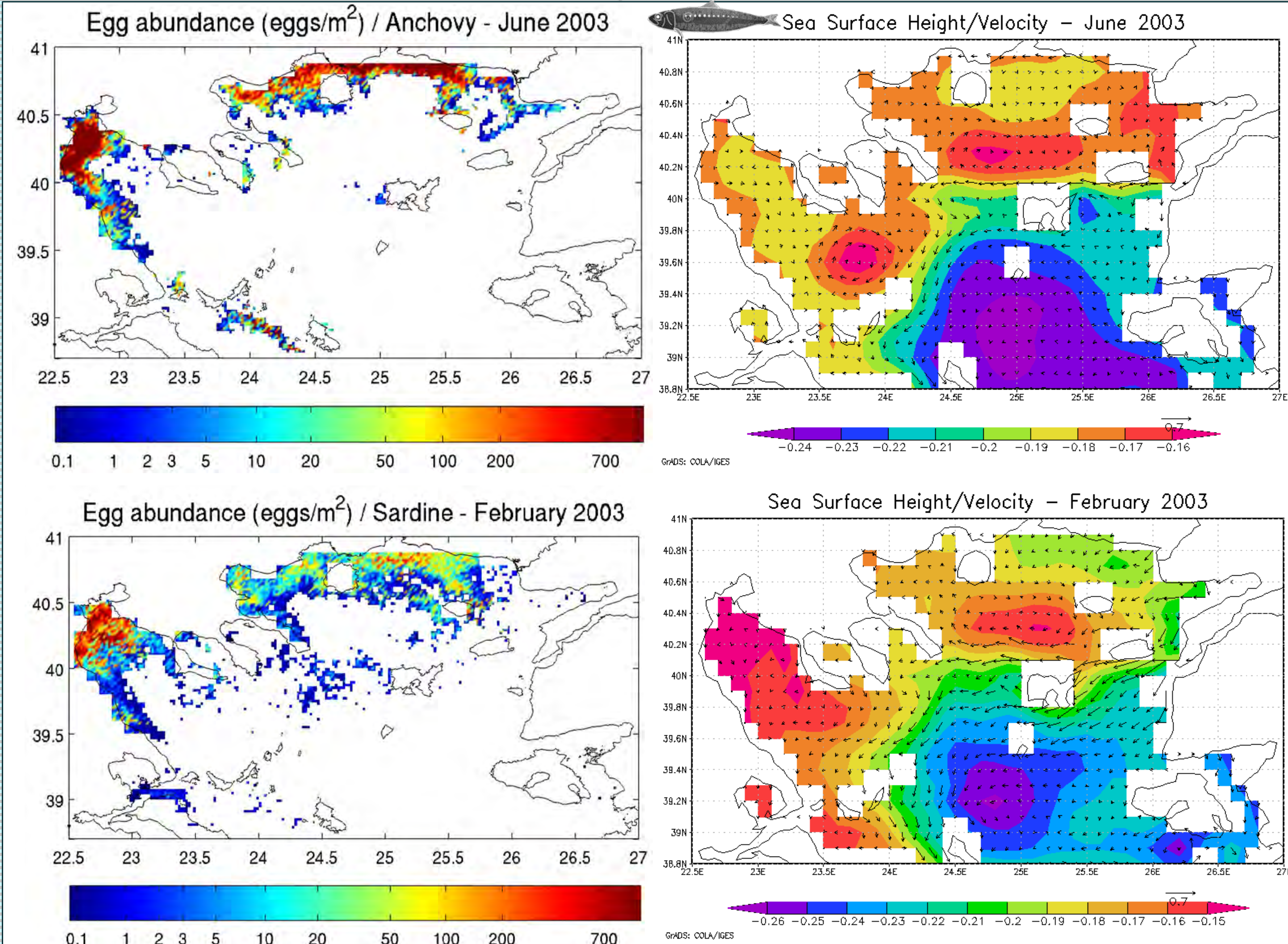
Available data for anchovy and sardine:

- Total anchovy biomass estimated at ~ 40ktns and total sardine biomass estimated at ~20ktns
- Sardine biomass estimation from acoustic surveys:2004-2007

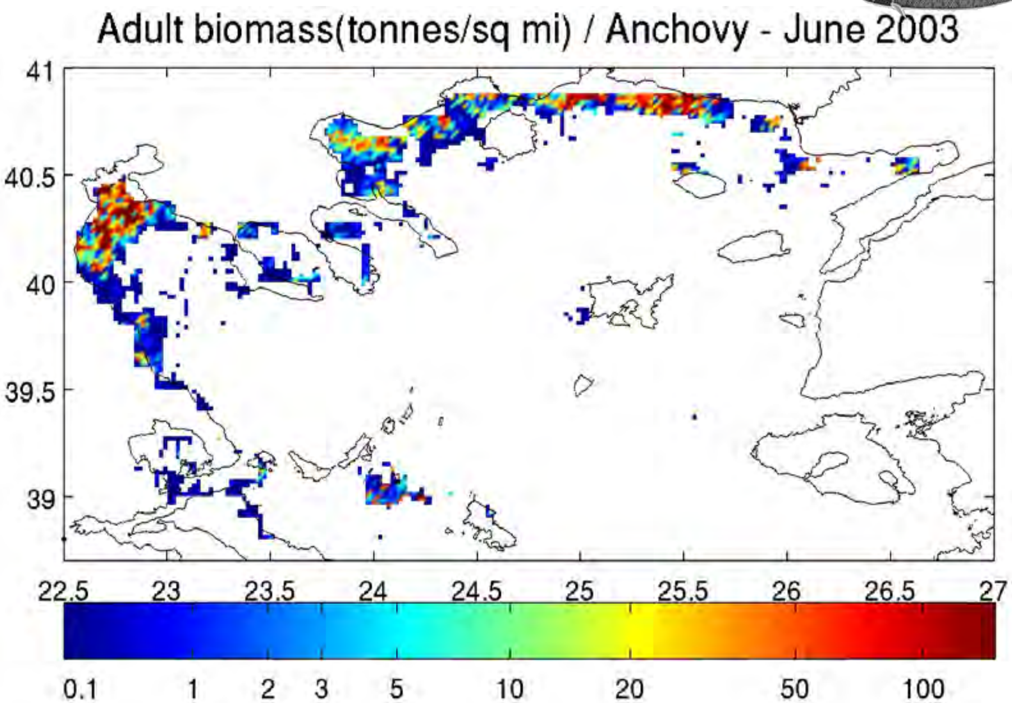


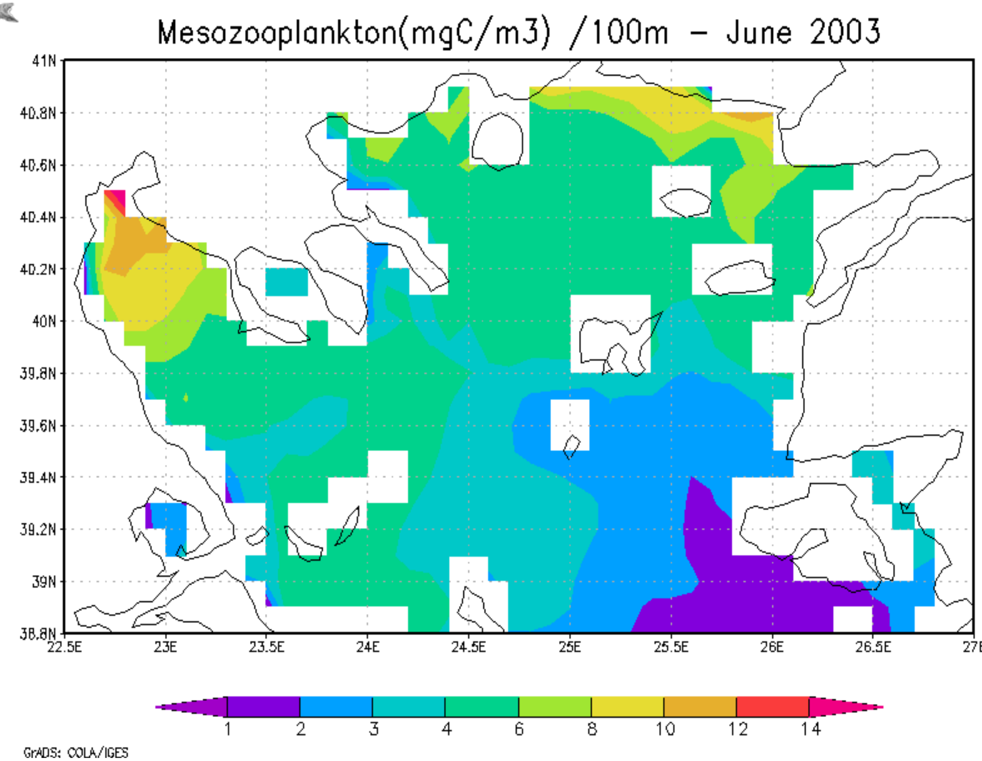
Anchovy and Sardine weight

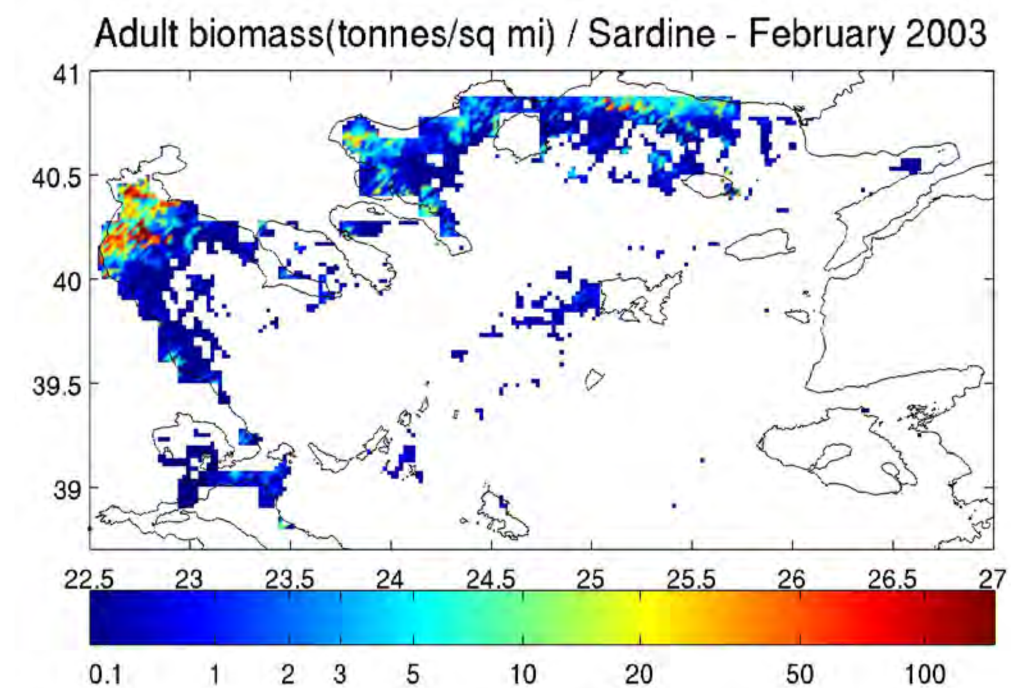


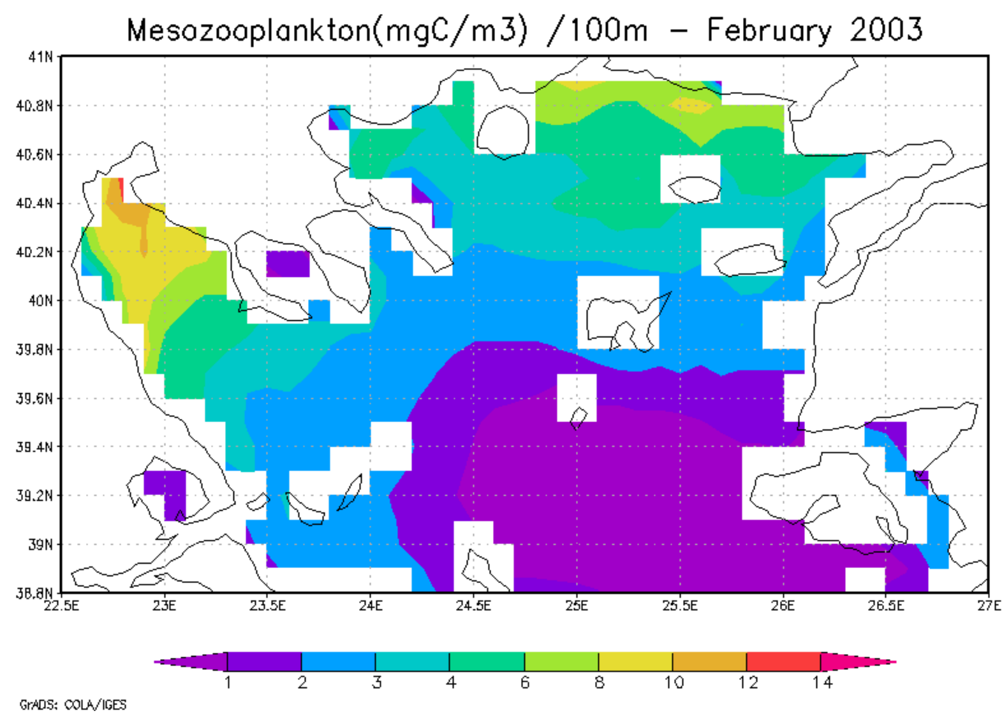


Egg abundance (eggs/m2) / Anchovy - June 2003
41
40.5
40
39.5
39
22.5 23 23.5 24 24.5 25 25.5 26 26.5 27
0.1 1 2 3 5 10 20 50 100 200 700
Sea Surface Height/Velocity – June 2003
41N 40.8N 40.6N 40.4N 40.2N 40N 39.8N 39.6N 39.4N 39.2N 39N 38.8N
22.5E 23E 23.5E 24E 24.5E 25E 25.5E 26E 26.5E 27E
0.7
–0.24 –0.23 –0.22 –0.21 –0.2 –0.19 –0.18 –0.17 –0.16
GrADS: COLA/IGES
Egg abundance (eggs/m2) / Sardine - February 2003
41
40.5
40
39.5
39
22.5 23 23.5 24 24.5 25 25.5 26 26.5 27
0.1 1 2 3 5 10 20 50 100 200 700
Sea Surface Height/Velocity – February 2003
41N 40.8N 40.6N 40.4N 40.2N 40N 39.8N 39.6N 39.4N 39.2N 39N 38.8N
22.5E 23E 23.5E 24E 24.5E 25E 25.5E 26E 26.5E 27E
0.7
–0.26 –0.25 –0.24 –0.23 –0.22 –0.21 –0.2 –0.19 –0.18 –0.17 –0.16 –0.15
GrADS: COLA/IGES

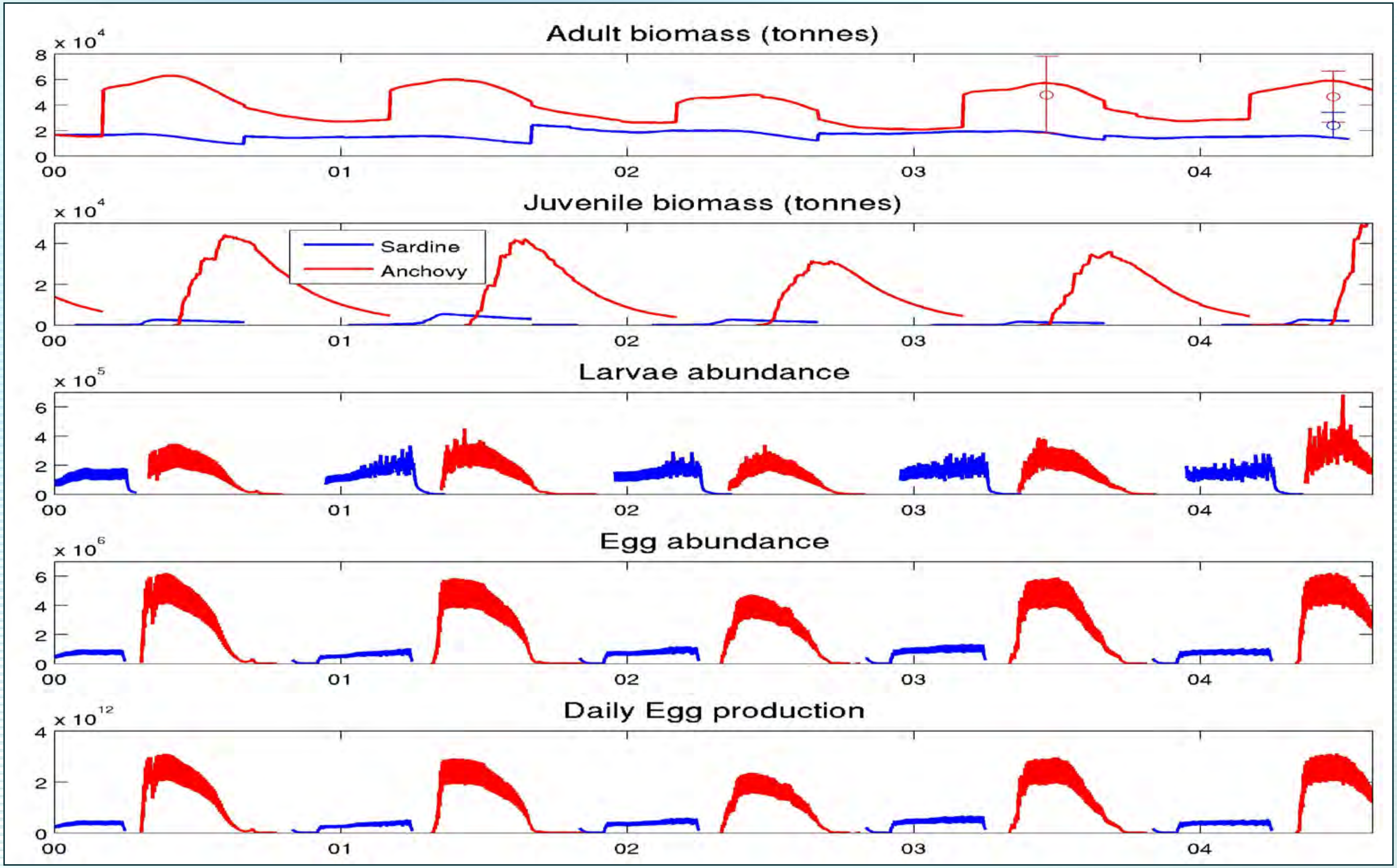

Adult biomass(tonnes/sq mi) / Anchovy - June 2003
41
40.5
40
39.5
39
22.5 23 23.5 24 24.5 25 25.5 26 26.5 27
0.1 1 2 3 5 10 20 50 100


Mesozooplankton(mgC/m3) /100m – June 2003
41N 40.8N 40.6N 40.4N 40.2N 40N 39.8N 39.6N 39.4N 39.2N 39N 38.8N
22.5E 23E 23.5E 24E 24.5E 25E 25.5E 26E 26.5E 27E
1 2 3 4 6 8 10 12 14
GrADS: COLA/IGES

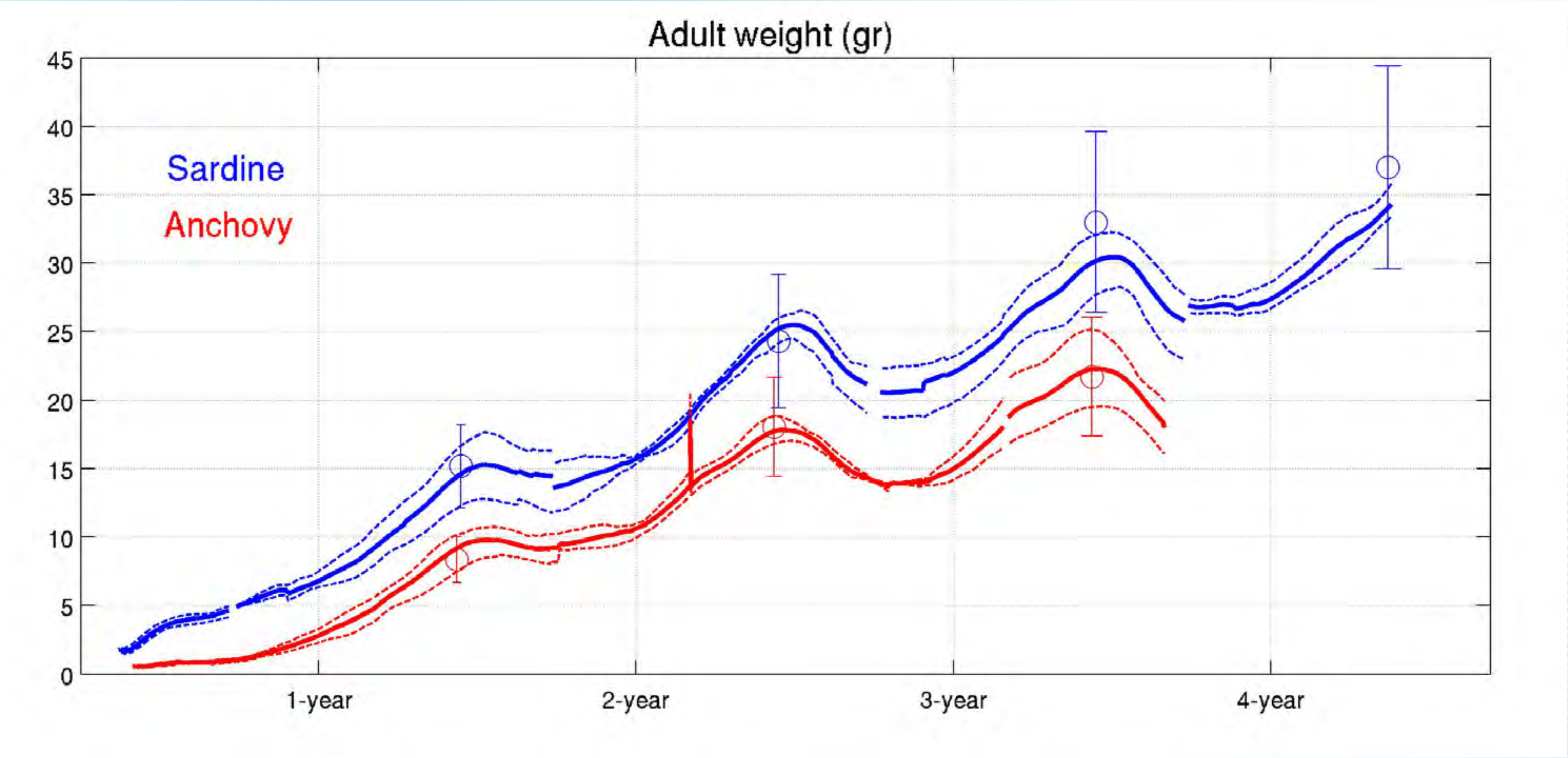

Adult biomass(tonnes/sq mi) / Sardine - February 2003
41
40.5
40
39.5
39
22.5 23 23.5 24 24.5 25 25.5 26 26.5 27
0.1 1 2 3 5 10 20 50 100


Mesozooplankton(mgC/m3) /100m – February 2003
41N 40.8N 40.6N 40.4N 40.2N 40N 39.8N 39.6N 39.4N 39.2N 39N 38.8N
22.5E 23E 23.5E 24E 24.5E 25E 25.5E 26E 26.5E 27E
1 2 3 4 6 8 10 12 14
GrADS: COLA/IGES

Anchovy Sardine 3D simulation



Sardine and Anchovy Adult weight

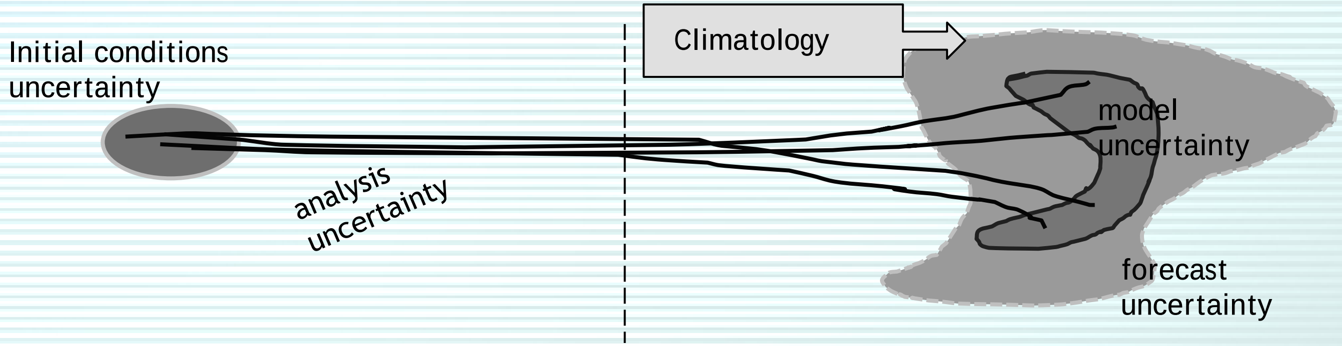


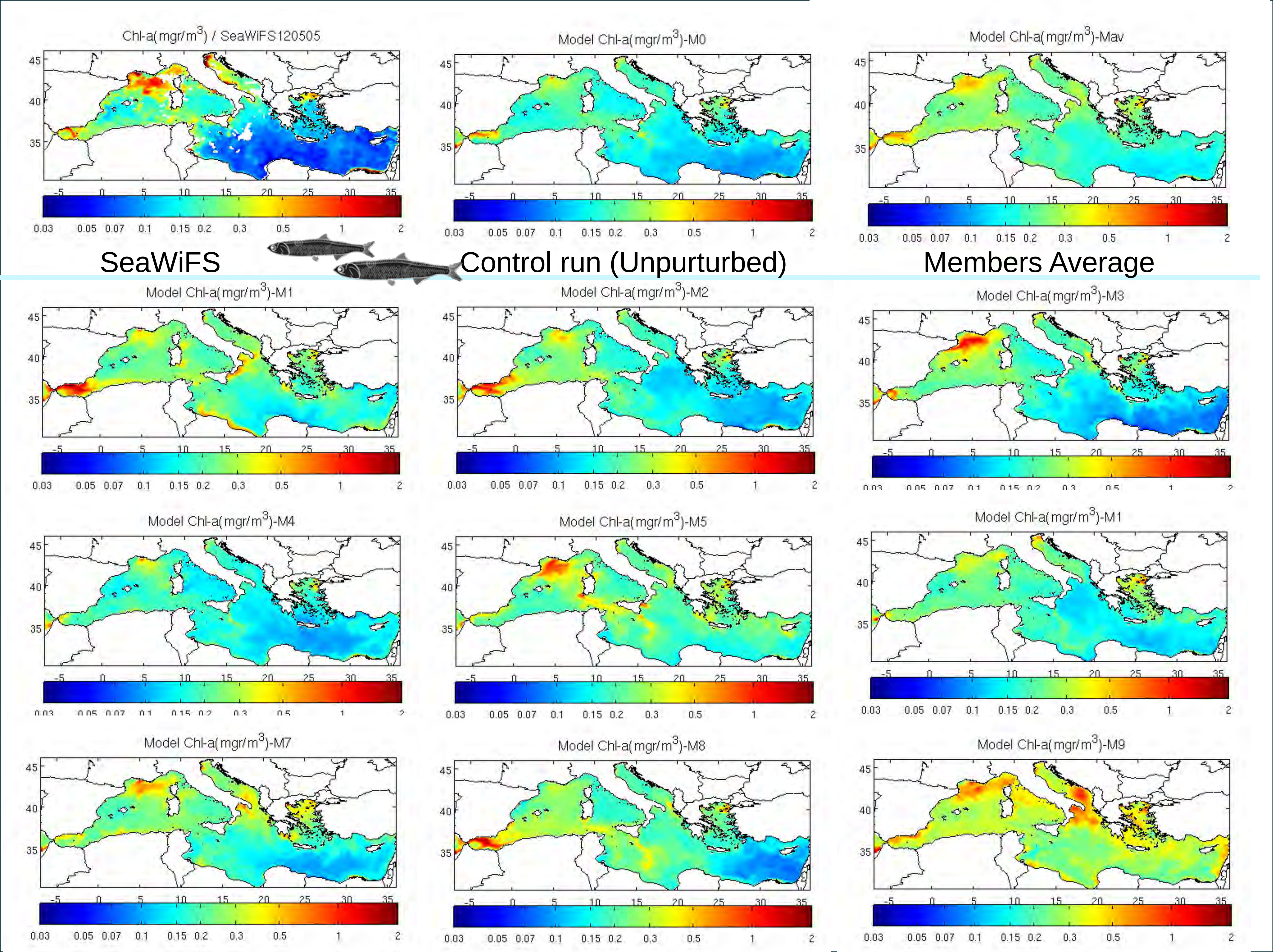
The Rational behind ensemble simulations

- There are two key **sources of uncertainties** that limit the skill of single, deterministic forecasts in an unpredictable way
- **Initial conditions** uncertainties (always be known only approximately) (Lorenz, C. E., 1965)
- **Unresolved processes** that are active at scales smaller than the grid size. **Parameterization** is used for the key reasons of ***model uncertainties***

Ensemble simulations

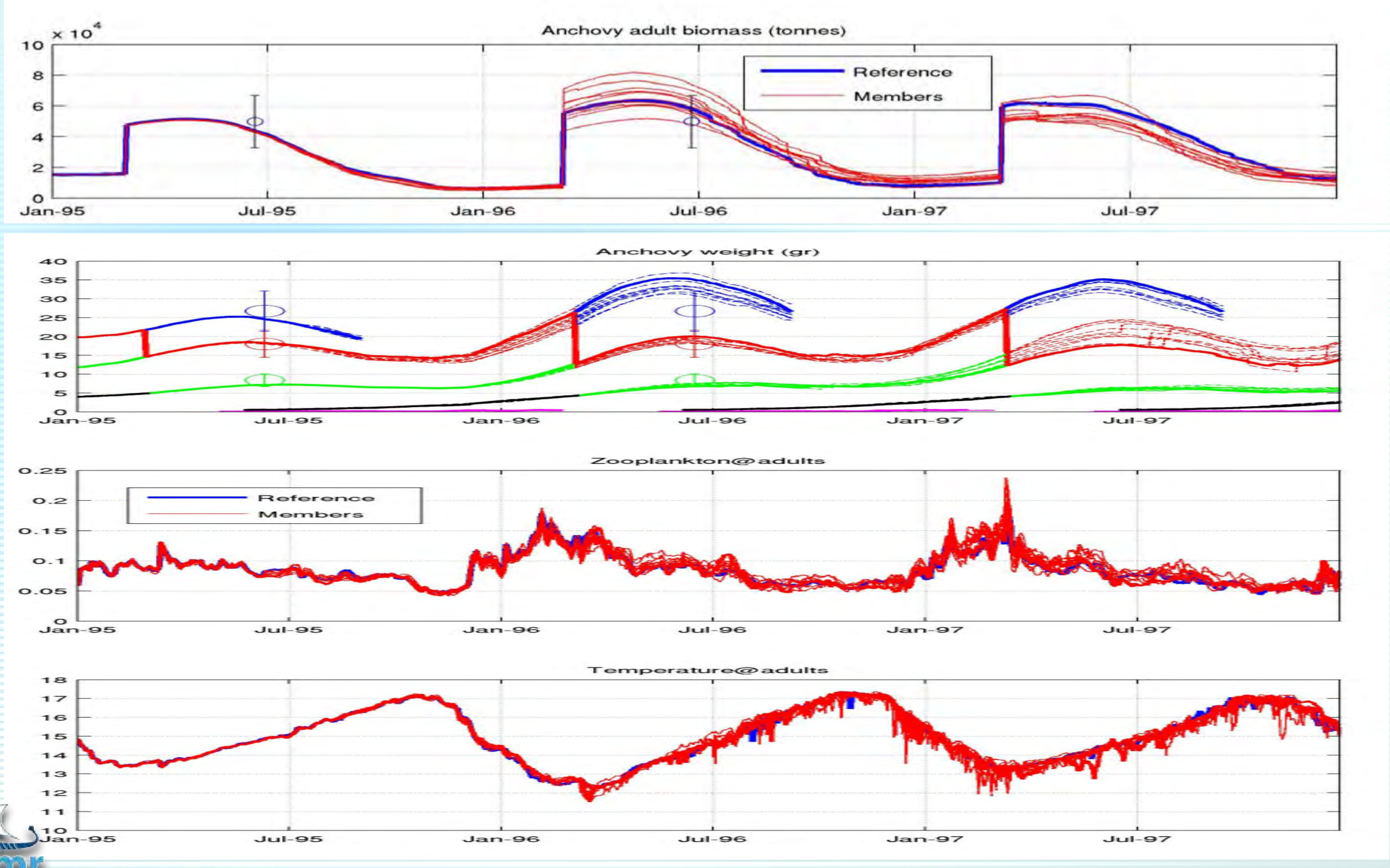
- Atmospheric forcing from 20 year hind-cast (1990-2009) was used to extract the dominant variability performing EOF analysis.
- EOFs and the Kalman filter “second order exact sampling” technique generate an ensemble of atmospheric forcing representative of the inter-annual/seasonal variability



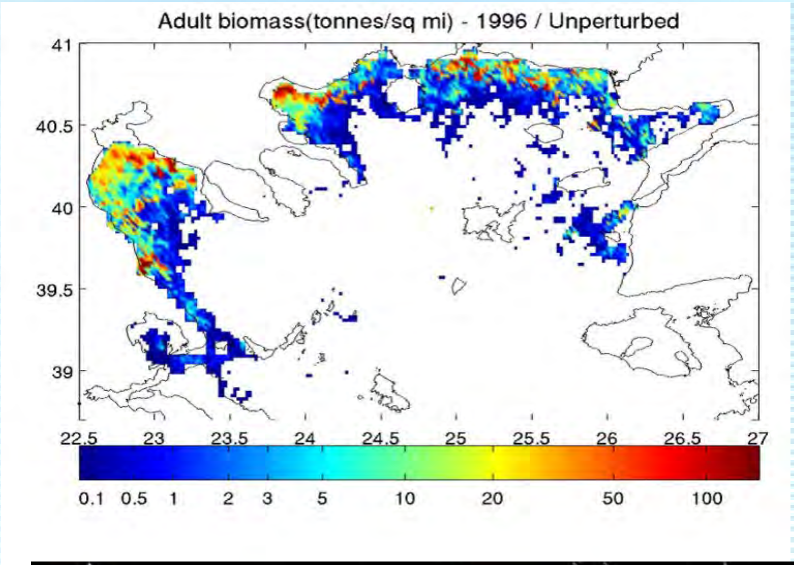


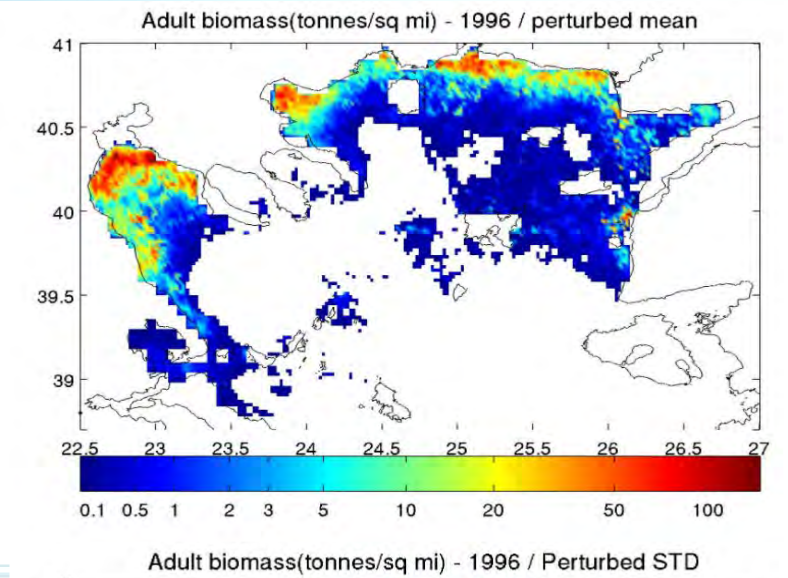
Chl-a(mgr/m^3) / SeaWiFS120505
Model Chl-a(mgr/m^3)-M0
Model Chl-a(mgr/m^3)-Mav
SeaWiFS
Control run (Unpurturbed)
Members Average
Model Chl-a(mgr/m^3)-M1
Model Chl-a(mgr/m^3)-M2
Model Chl-a(mgr/m^3)-M3
Model Chl-a(mgr/m^3)-M4
Model Chl-a(mgr/m^3)-M5
Model Chl-a(mgr/m^3)-M1
Model Chl-a(mgr/m^3)-M7
Model Chl-a(mgr/m^3)-M8
Model Chl-a(mgr/m^3)-M9
45 40 35
-5 0 5 10 15 20 25 30 35
0.03 0.05 0.07 0.1 0.15 0.2 0.3 0.5 1 2

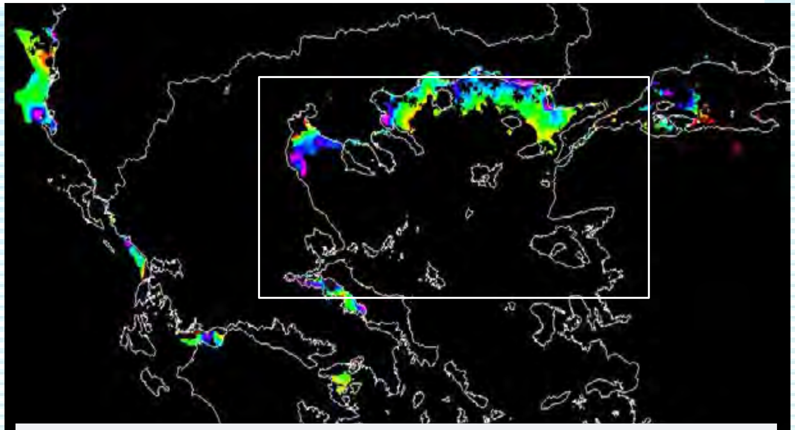
Ensemble Simulations



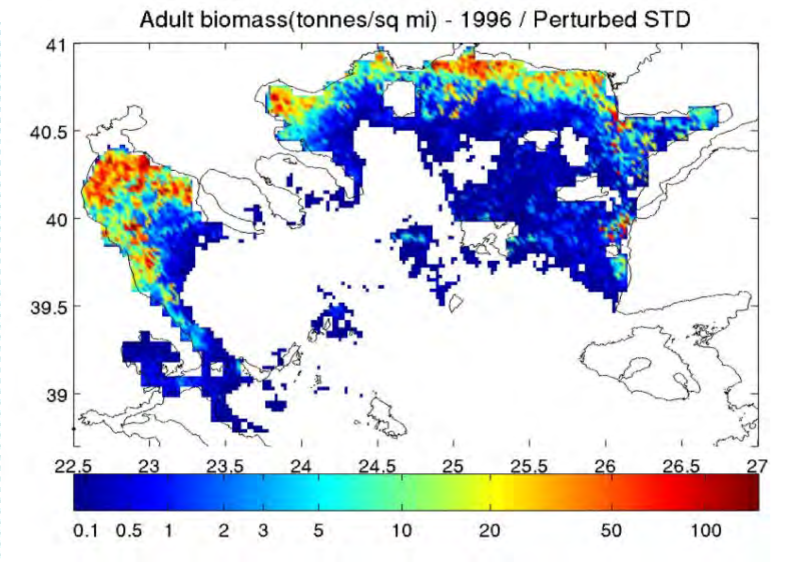
Anchovy adult biomass distribution



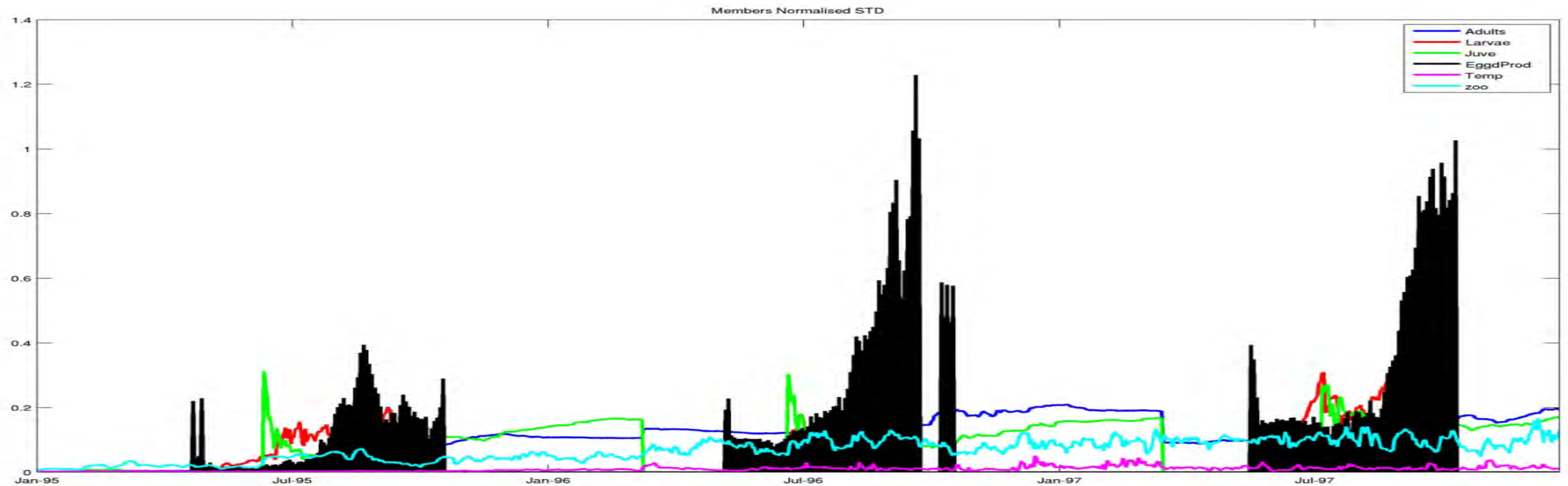


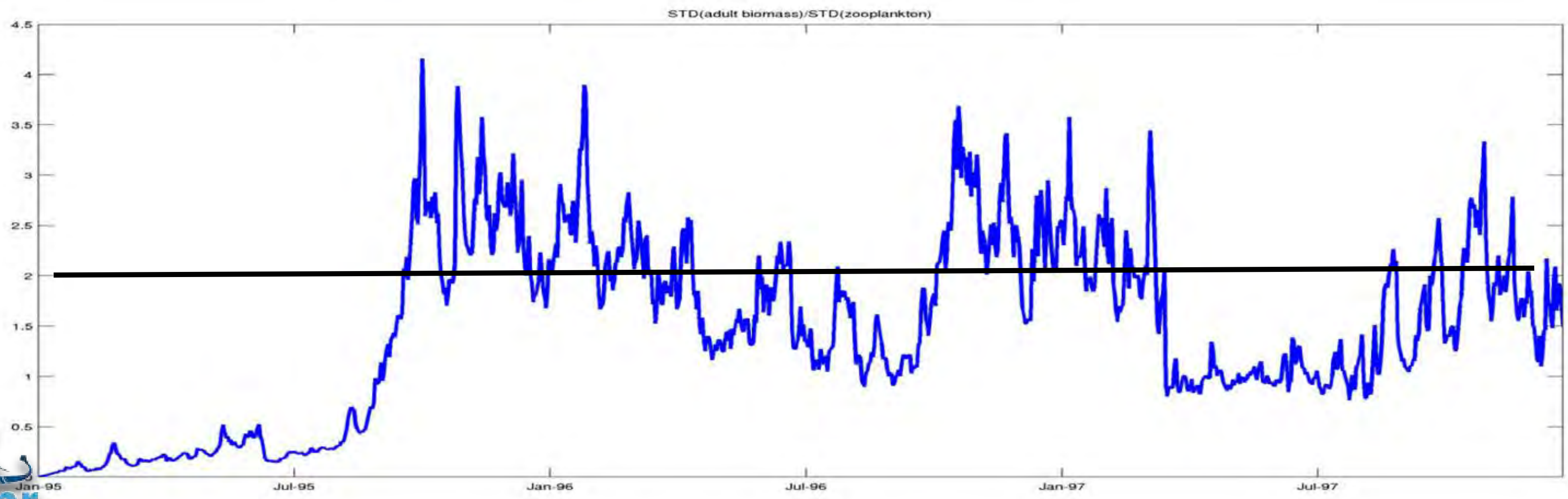


Anchovy habitat map (Giannoulaki et al., 2010)



Members normalized STD and STD(fish biomass) / STD(zoo)





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Conclusions

- ✓ The coupling of physics and LTL with the two models - sardine and anchovy - that include all life stages, described the main features of small pelagic fish
- ✓ Model uncertainties are described by generating an ensemble of initial perturbations
- ✓ Ensemble predictions in small pelagic fish are valuable as they offer an estimate of the most probable future state of a system and provide the range of possible future outcomes

THANK YOU