European Geosciences Union
Dipartimento di Fisica
Università degli Studi di Genova

FOAM, THE NEW BENTHIC DEGRADATION MODEL AND ITS CALIBRATION IN MEDITERRANEAN CONDITION: AN APPLICATION TO A FISH FARM

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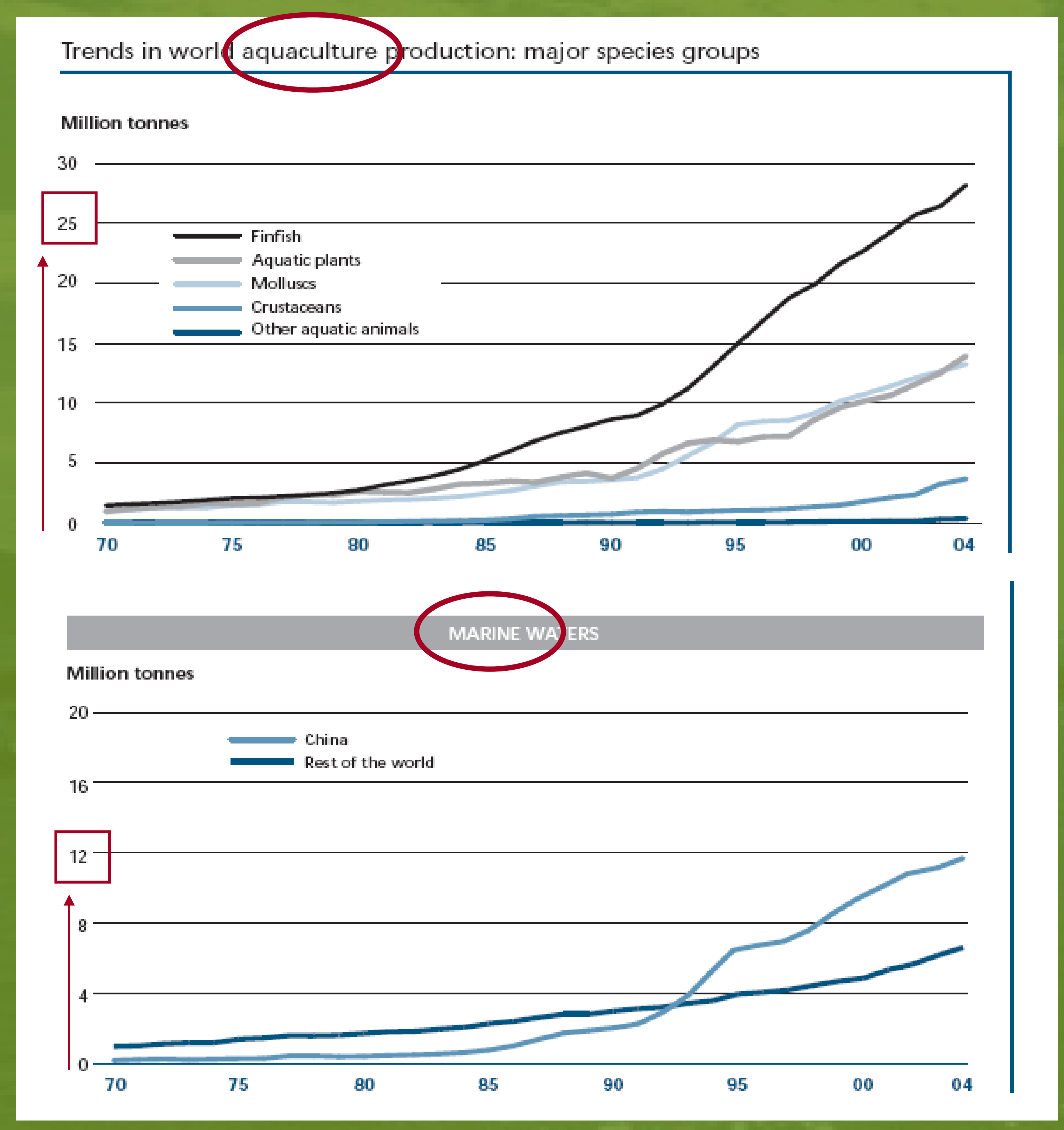
EGU - General Assembly 2009

Why aquaculture?



Potential impact on surrounding environment

★ Particulate waste

⇩

Numerical models

- predictions and test different scenarios

⇩

advection-dispersion model POM-LAMP3D and the new coupled benthic module FOAM

evaluation and prediction of environmental impact

Model Setup

POM hydrodynamic model

Princeton Ocean Model

Blumberg & Mellor, 1987

LAMP3D dispersion model

Lagrangian Assessment for Marine Pollution 3D model

Doglioli, 2000

FOAM degradation module

Finite Organic Accumulation Module

De Gaetano et al., 2008

Single particle lagrangian model:

Imaginary particles with pollutant concentration and settling velocity

Particle position — *from ocean model* — *Random jump*

$$r_{n+1} - r_n = \langle v \rangle \Delta t + \xi_n$$

time step

Input:
depth-averaged velocity

Princeton Ocean Model
http://www.aos.princeton.edu/WWWPUBLIC/htdocs.pom/index.html

from POM home page

Output:
-3D velocity
-3D concentration in water column

FOAM

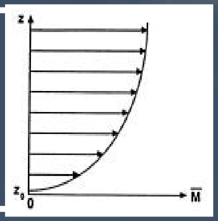
De Gaetano et al. (2008) *Aquac. Res.*, **39**:1229-1242

Index of impact

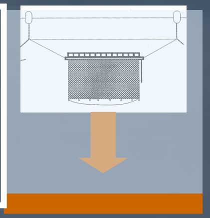
(Findlay and Watling, 1997)

$$I = \frac{O_2 \text{ supply } = A + B \log(V^{Bot})}{O_2 \text{ demand } = C\, Flx^{Bot} + D}$$

Bottom velocity



Carbon Flux



Input

LAMP3D

Lagrangian Assessment for Marine Pollution 3D model

FOAM

De Gaetano et al. (2008) *Aquac. Res.*, **39**:1229-1242

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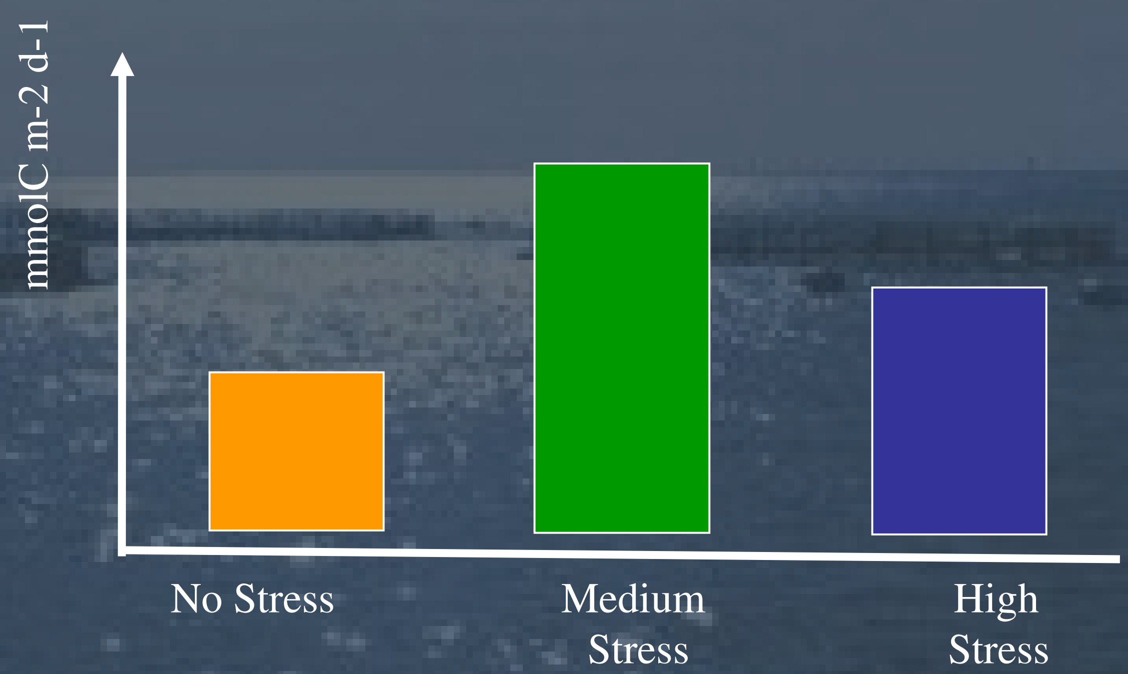
$$I = \frac{O_2\ \text{supply} = A + B \log\left(V^{Bot}\right)}{O_2\ \text{demand} = C\ Flx^{Bot} + D}$$

$I > 1.0$ → No stress

$I \sim 1.0$ → Medium stress

$I < 1.0$ → High Stress

Rate of mineralization



Output: Organic Carbon concentration at the bottom

FOAM

De Gaetano et al. (2008) *Aquac. Res.*, **39**:1229-1242

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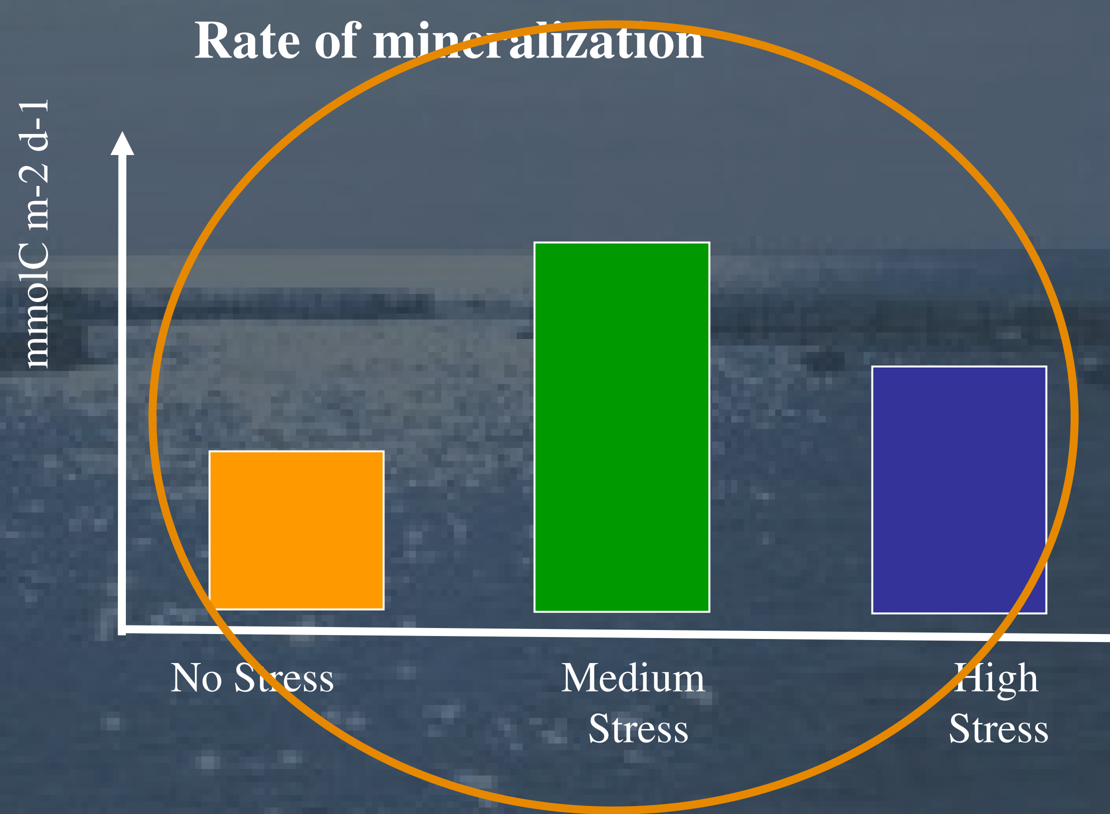
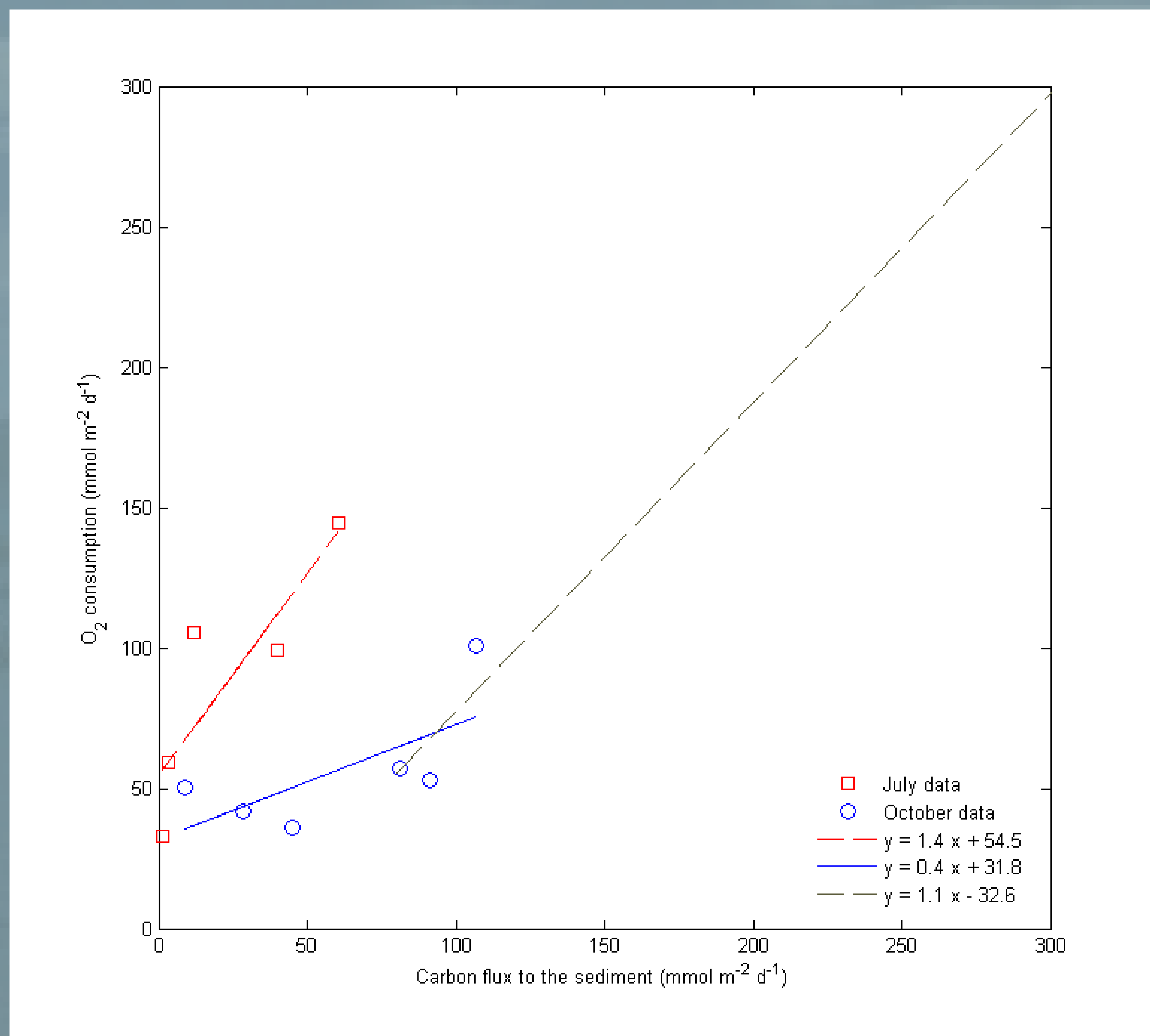


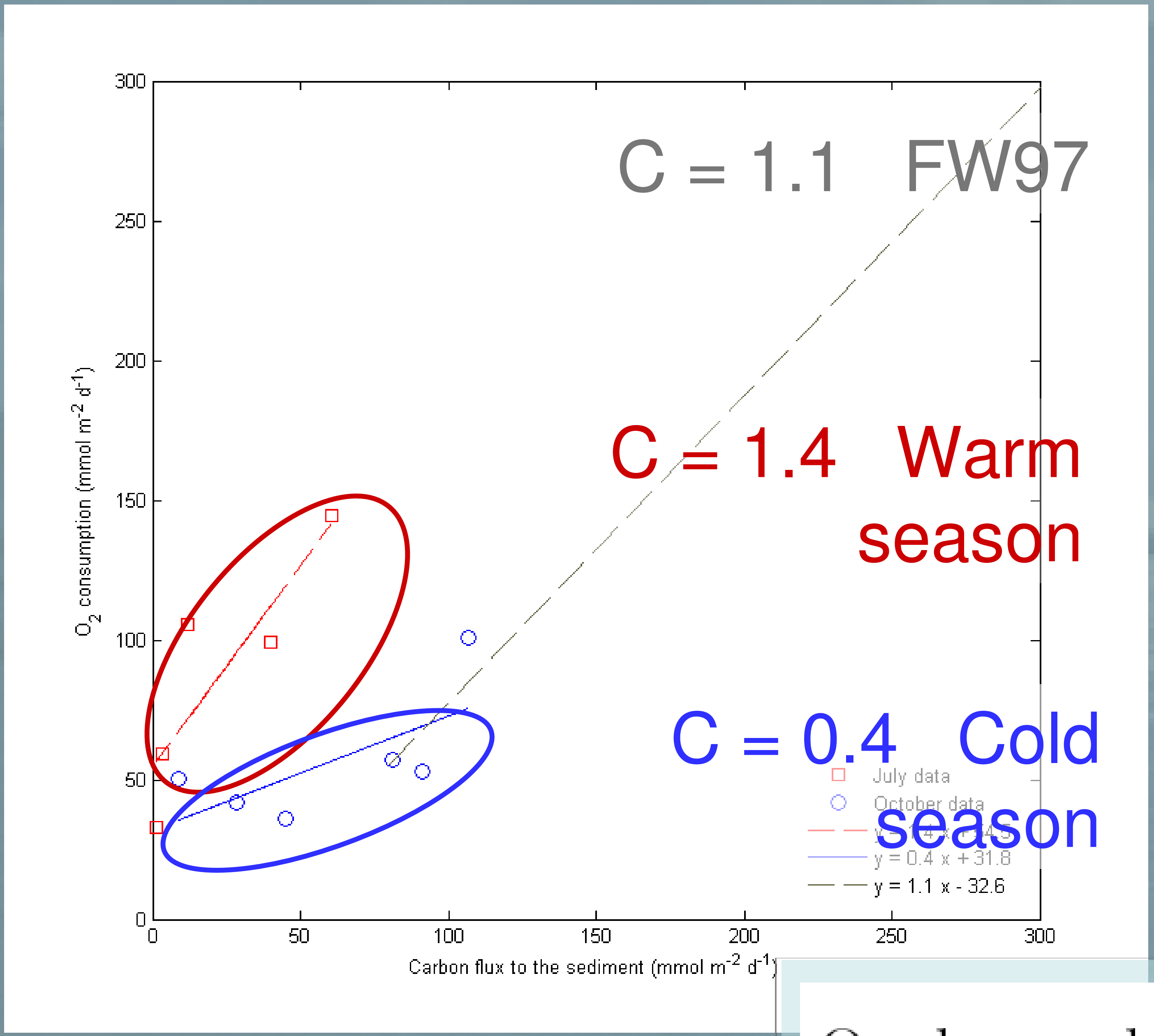
Two sampling campaign, July and October 2006, in a typical Mediterranean fish farm

Measures of O_2 consumption and C flux toward the sediment



Benthic metabolism

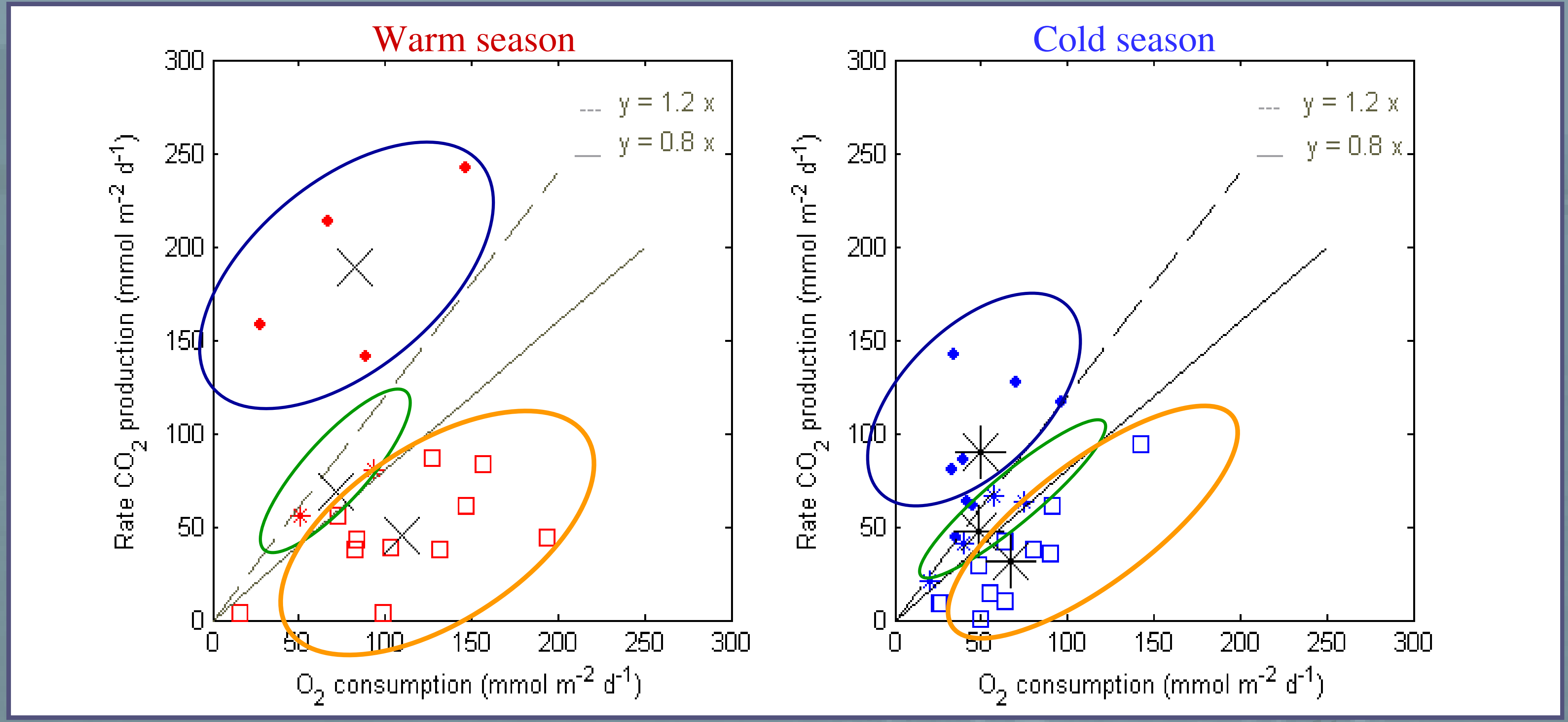
Depend on season



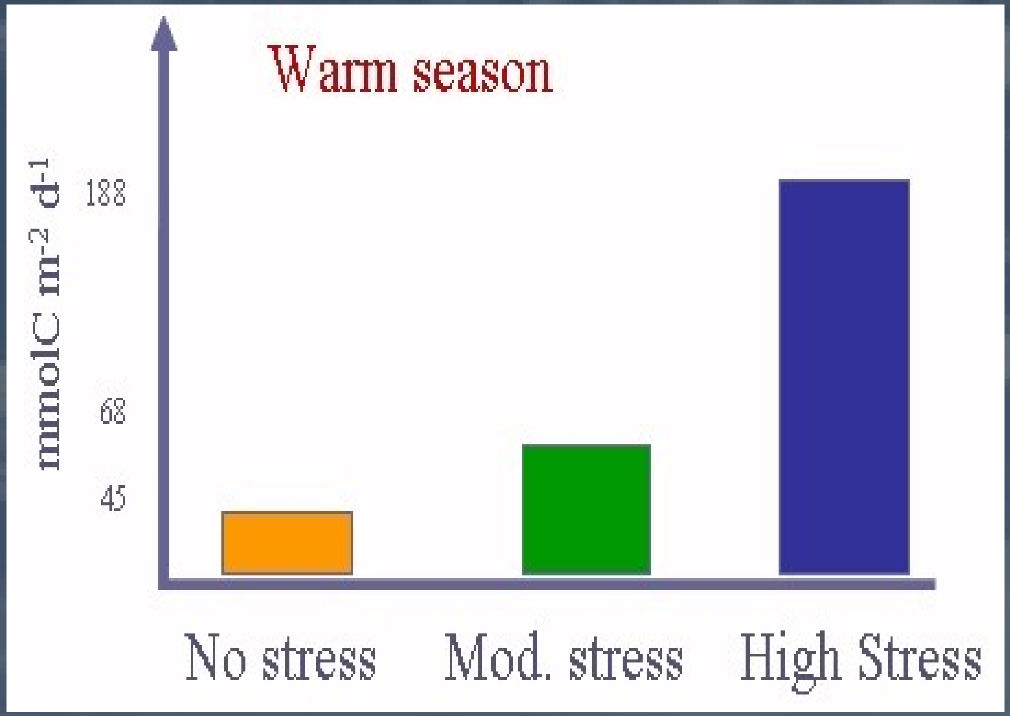
$$O_2 \text{ demand} = C\, Flx^{Bot} + D$$

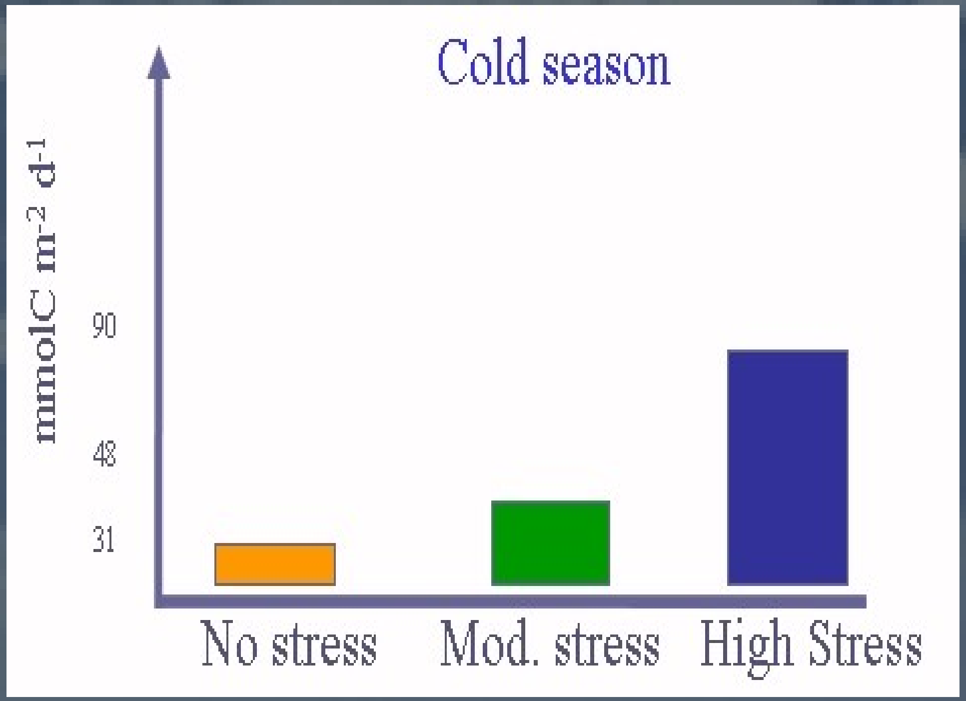
Benthic State

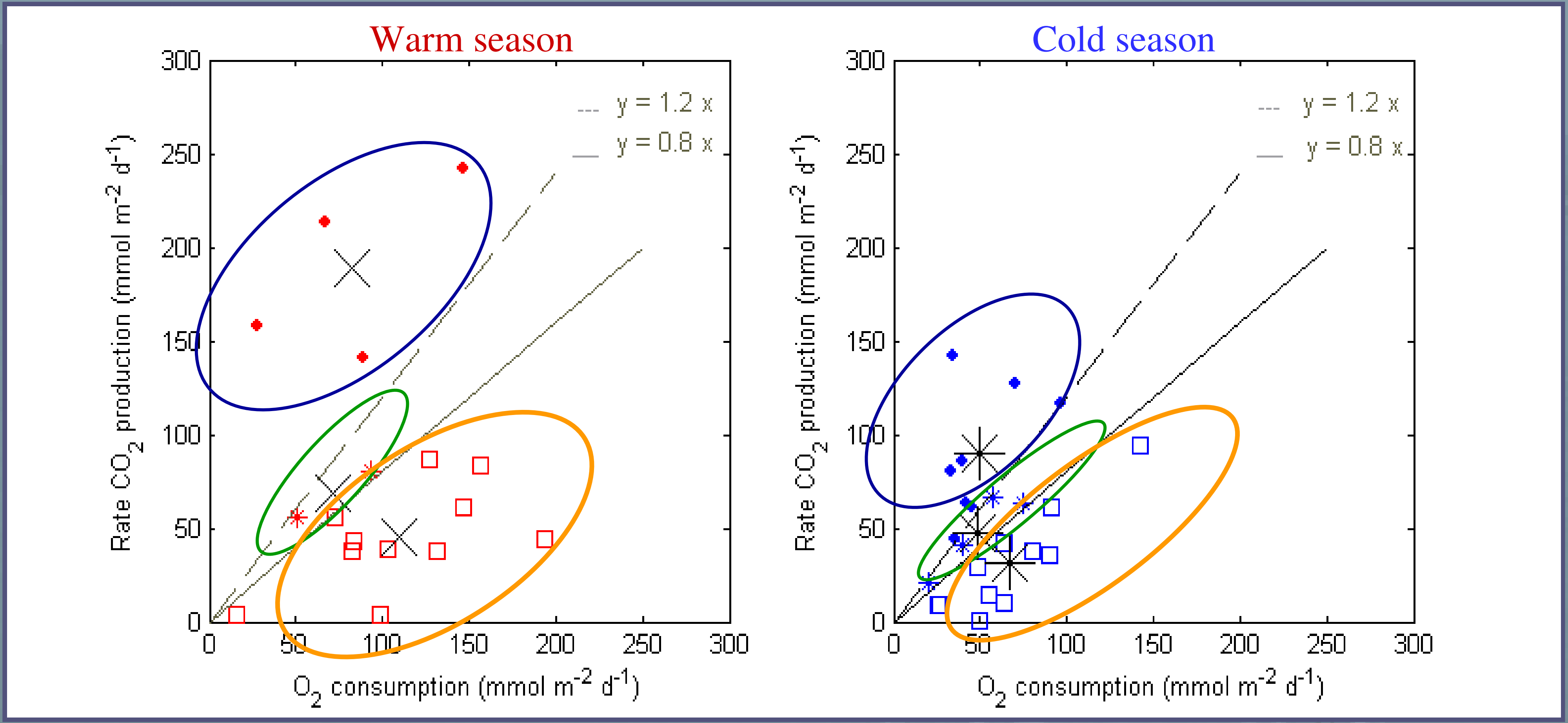
Measures of rate of CO_2 production and O_2 consumption



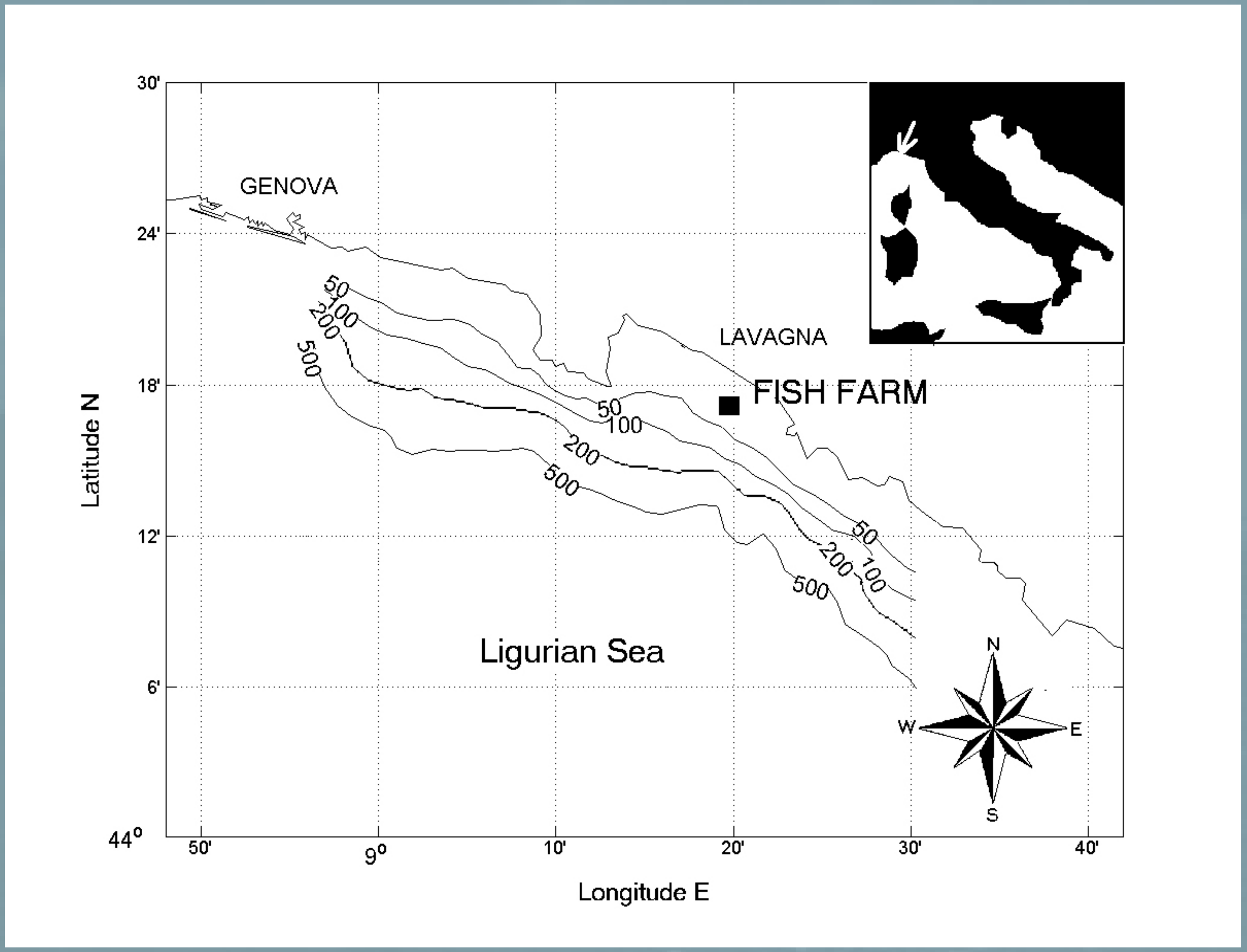
Benthic State



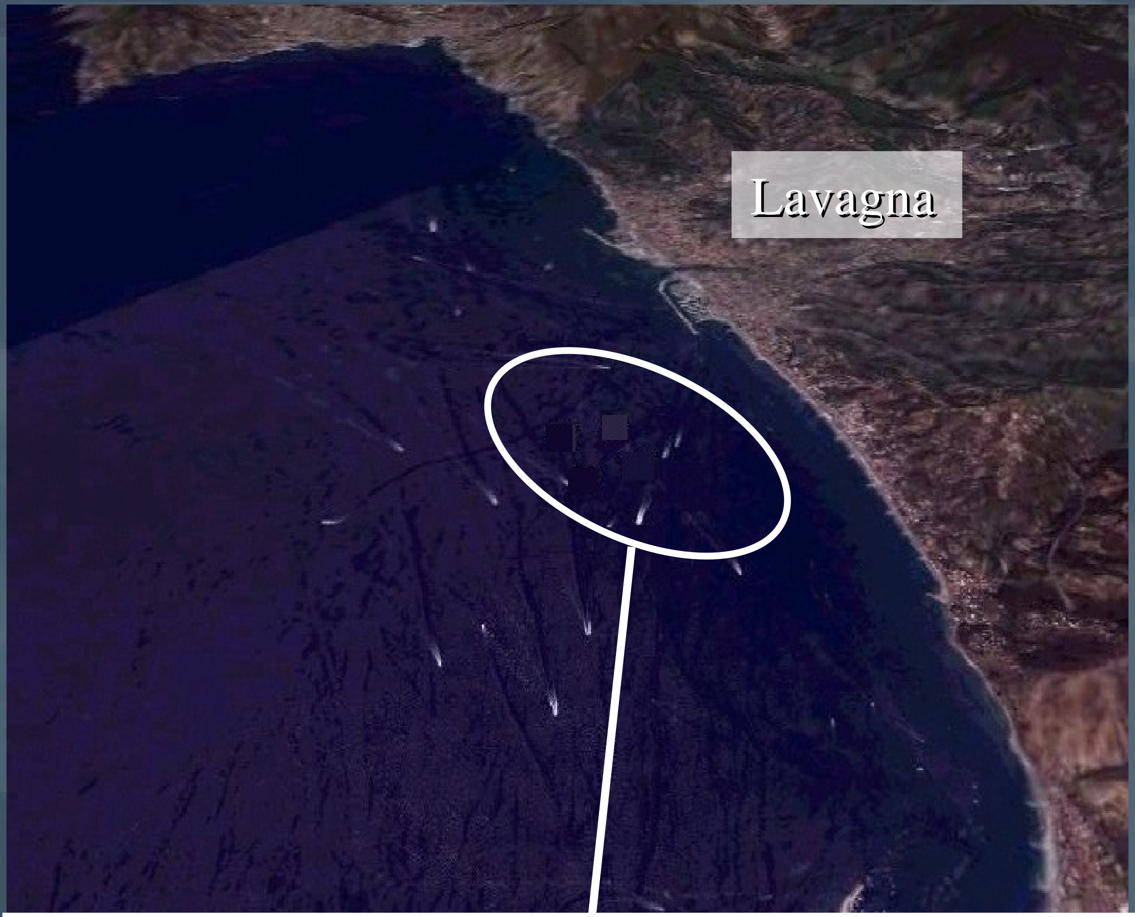




AQUA fish farm



AQUA fish farm



Productive target:
200 ton year $^{-1}$

Reared species:
Sparus aurata and
Dicentrarchus labrax

Settling velocity

Introduction
Model Setup
Application
Results
Conclusion

Values measured in Mediterranean conditions

Uneaten feed		Faecal pellets		
Diameter (mm)	V_{sed} (m s^{-1})	Species	size (g)	V_{sed} (m s^{-1})
3	0.087 ↓	*S. Aurata*	adult (380)	0.004 ↓
3.5	0.118	*S. Aurata*	young (60)	0.005
4.5	0.103	*D. Labrax*	adult (280)	0.006
5	0.144 ⇓	*D. Labrax*	young (80)	0.007 ⇓
6	0.088			

Vassallo et al. (2006)
Aquac. Res., **37**(2):119-126

Magill et al. (2006)
Aquaculture **251**(2-4):295-305

Different scenarios

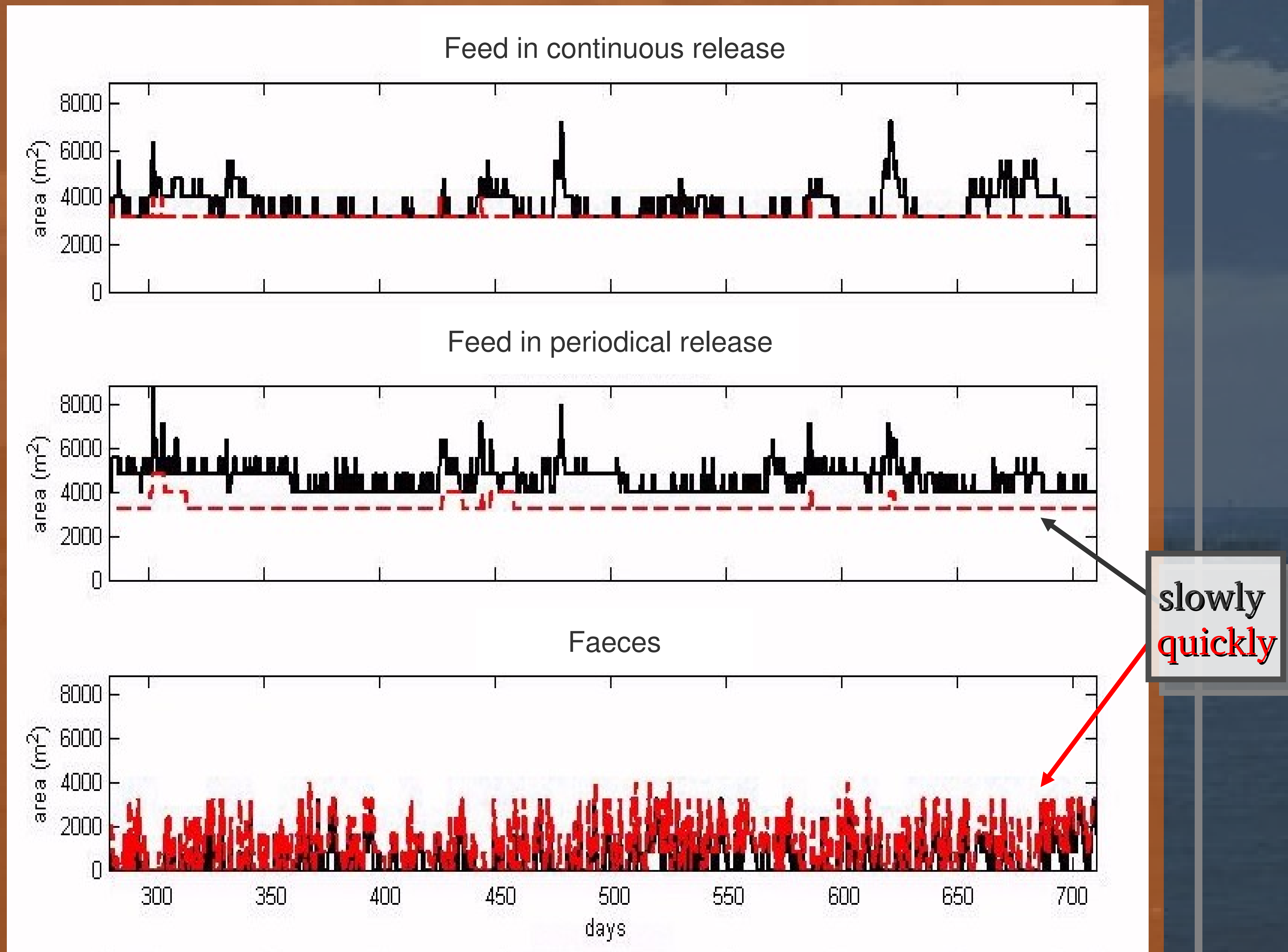
- waste typology → feed / faeces
- settling velocity → slowly / quickly
- release conditions → continuous / periodical

Indicators

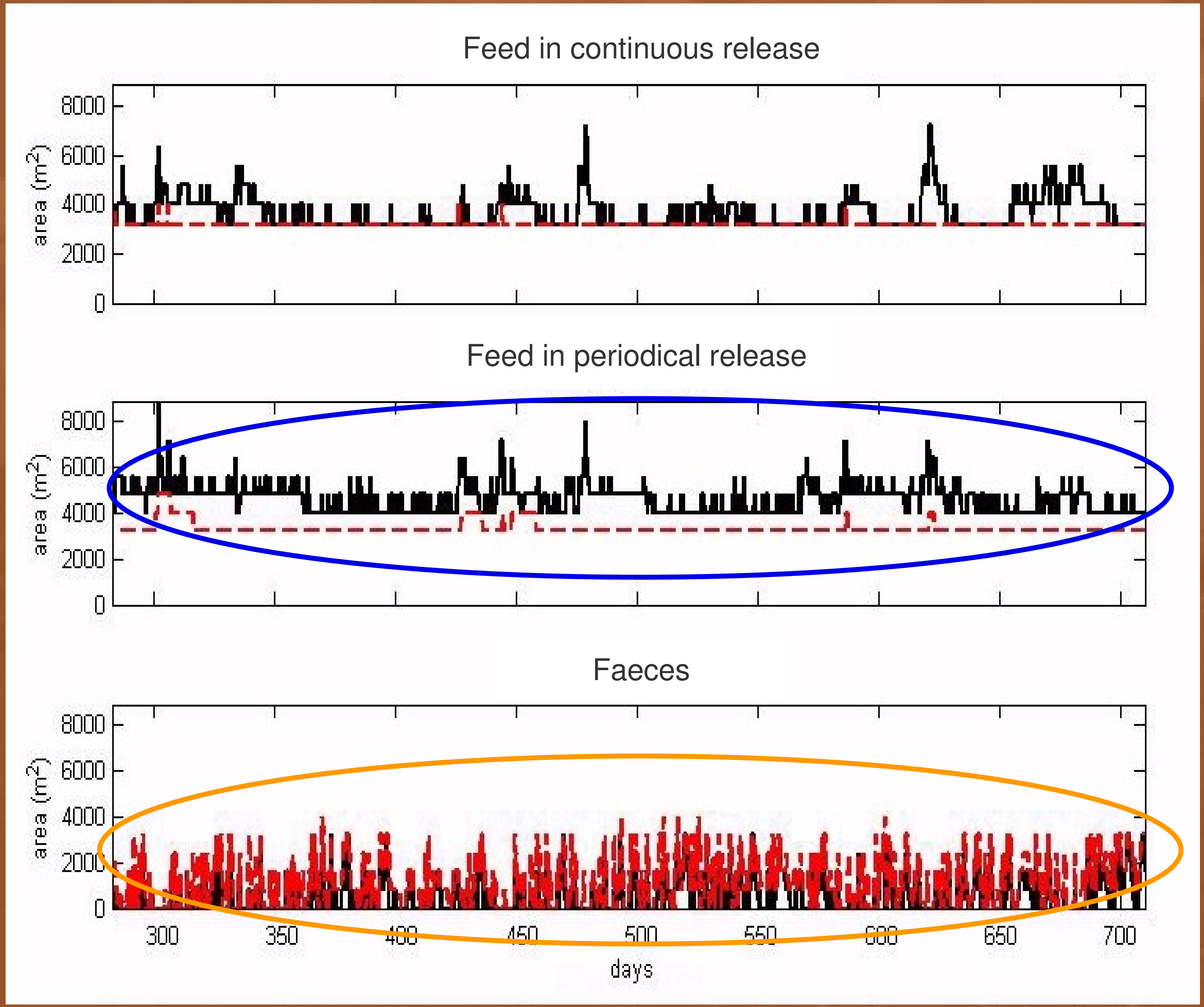
- Impacted area extension
- Organic Carbon concentration
- I parameter

Impacted Area

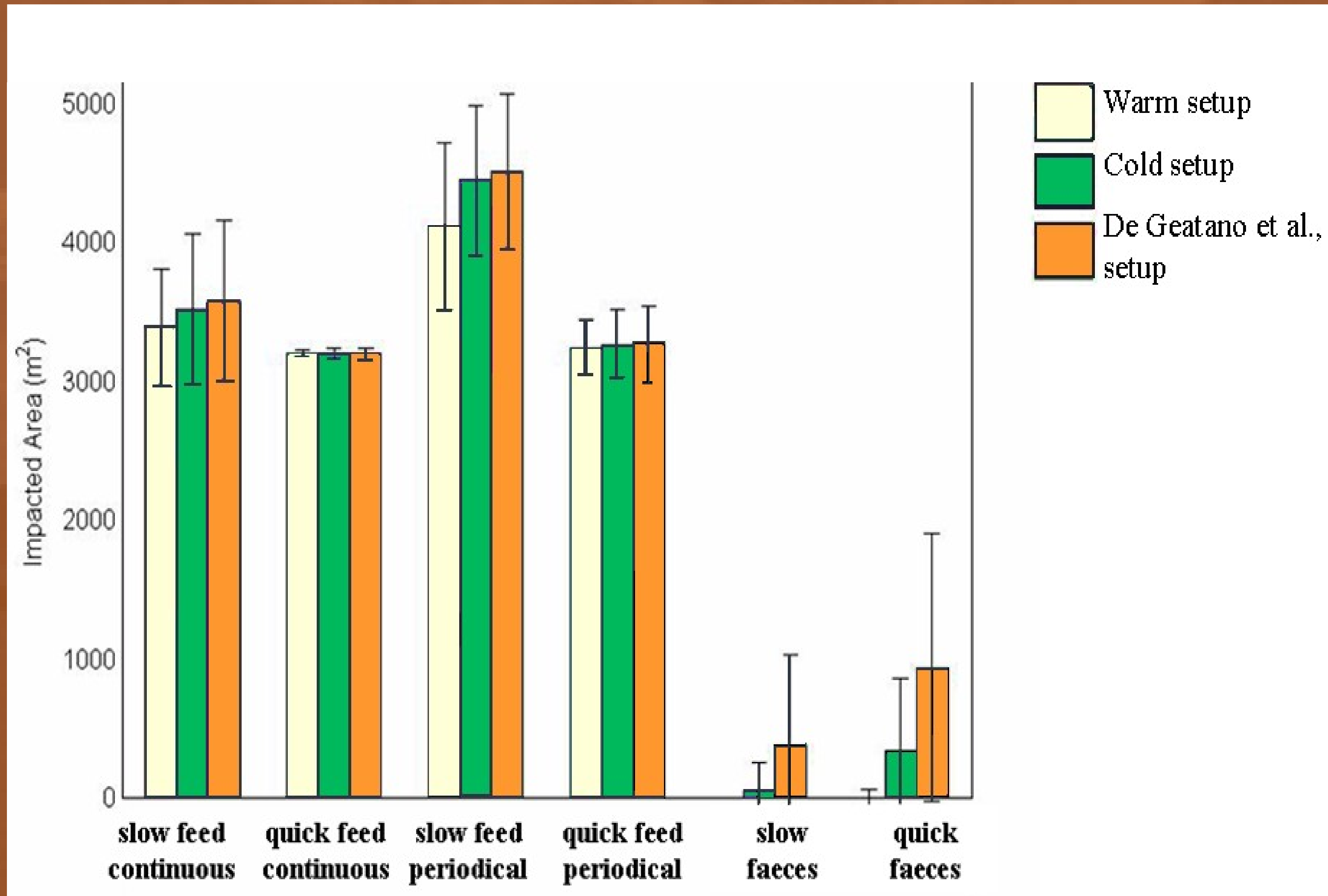
- Introduction
- Model Setup
- Application
- **Results**
- Conclusion



Impacted Area



Impacted Area



Impacted Area

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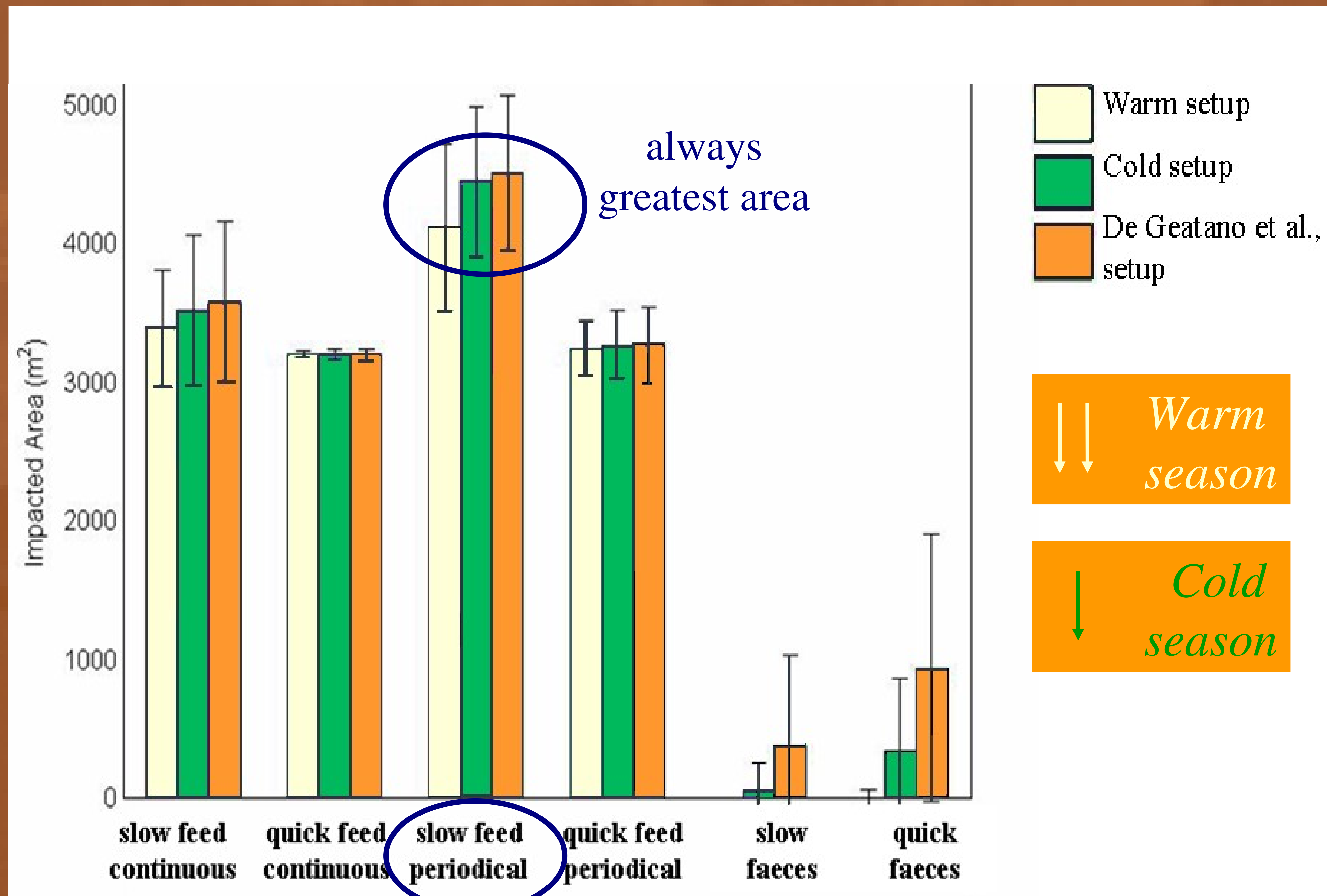
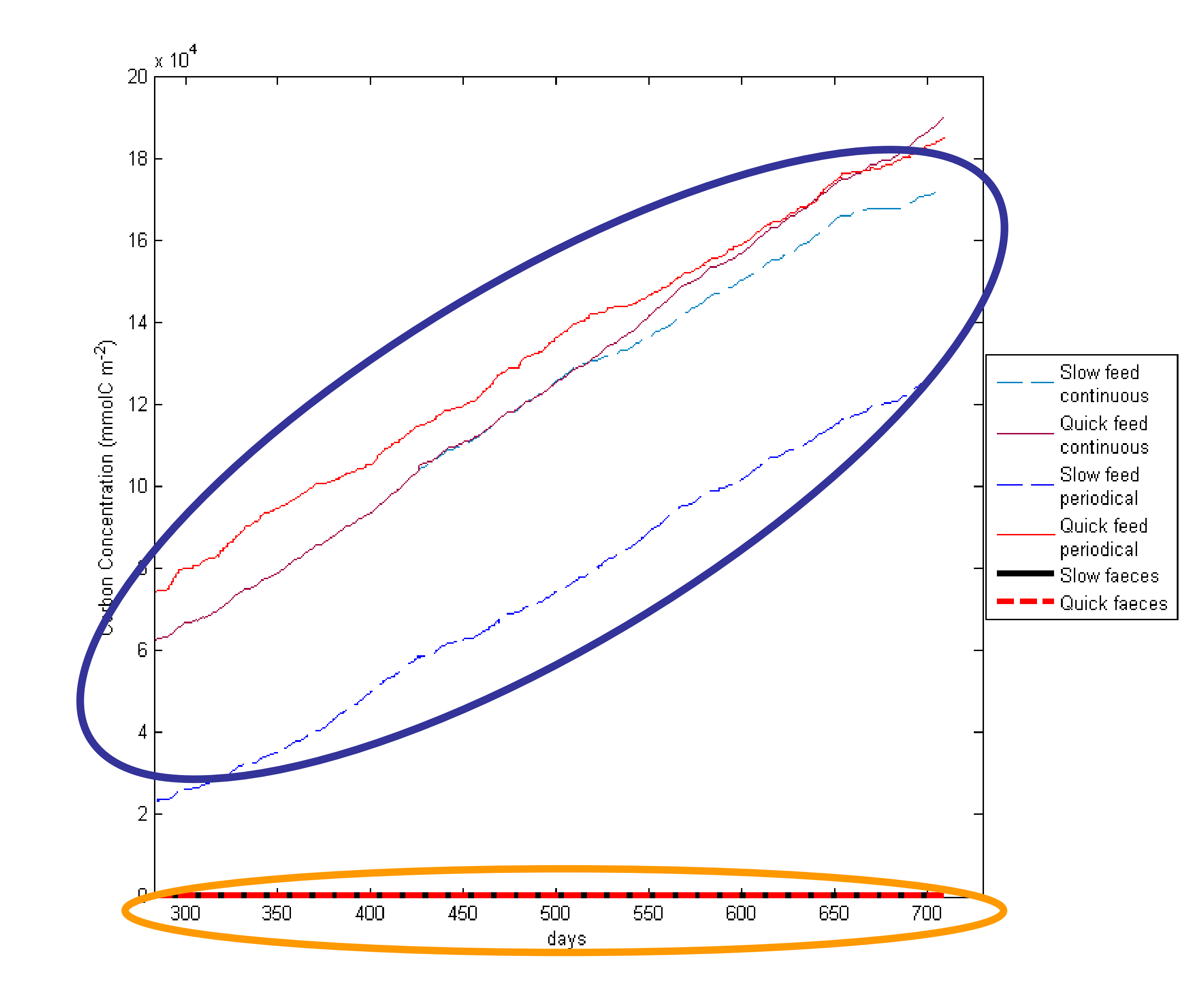


In De Gaetano et al. setup the impacted area was overestimated in all simulated scenarios

Carbon concentration

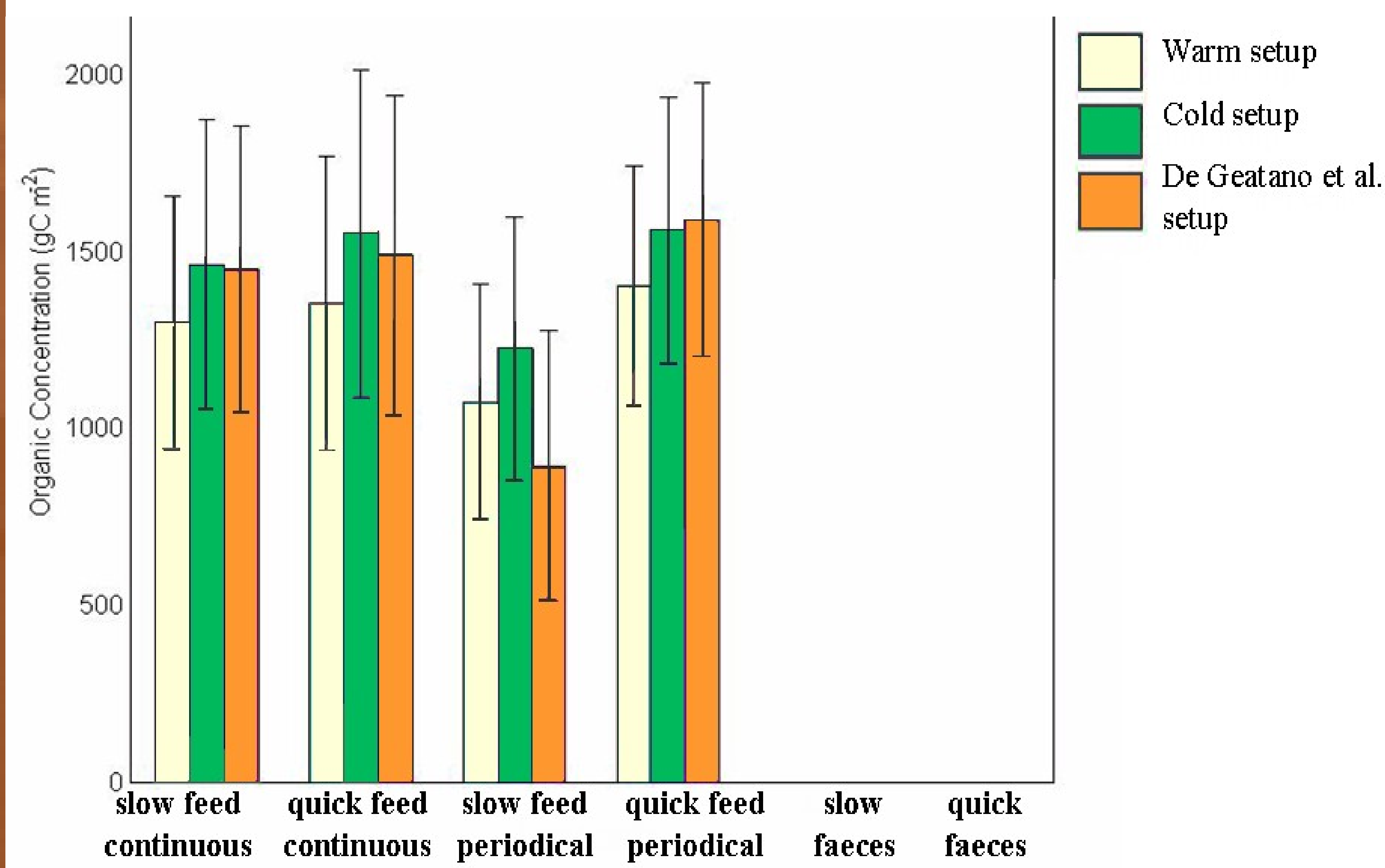
Time series



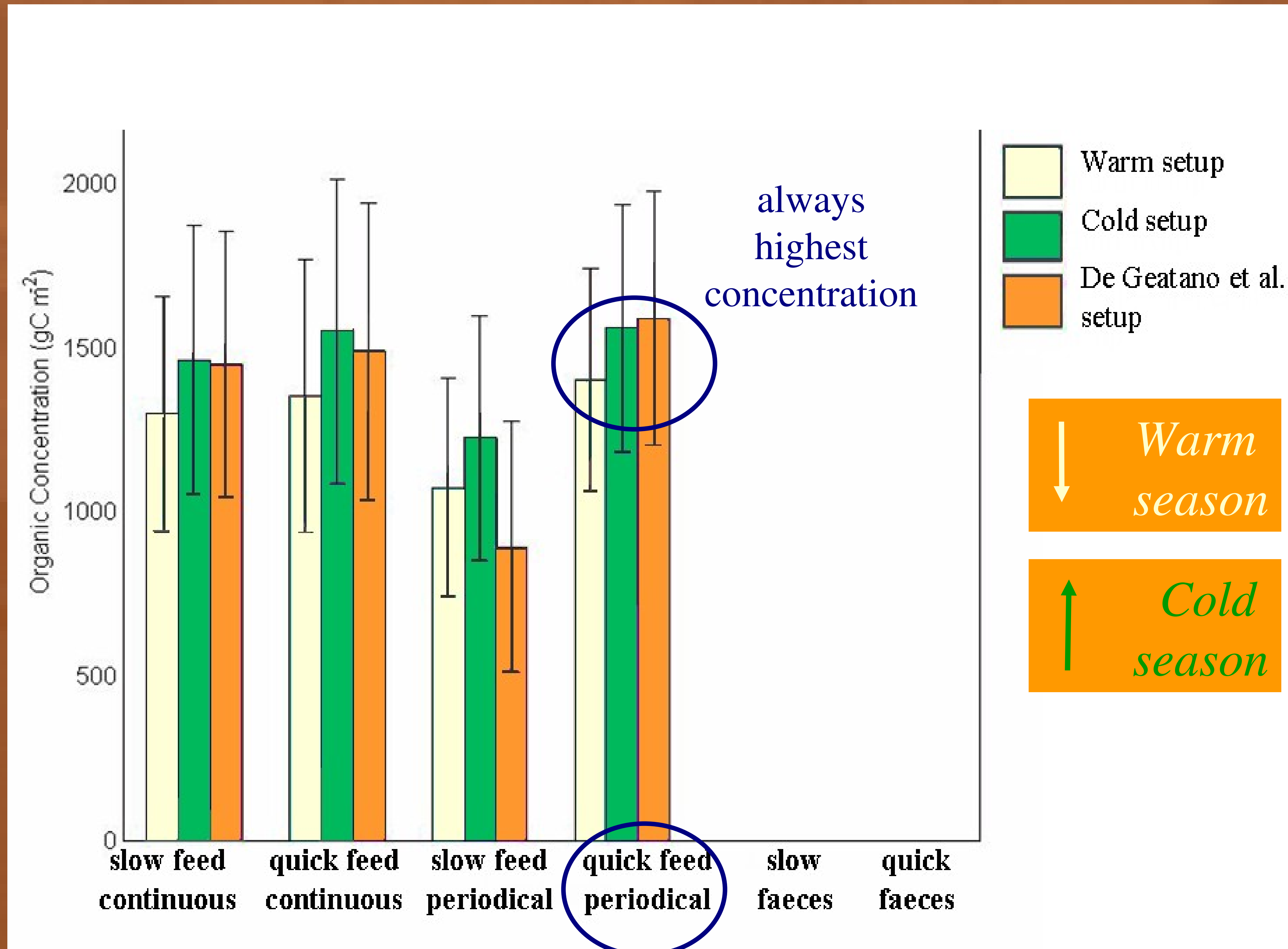
Time average

	mean ± std (gC m^{-2})
Slow feed continuous	1450 ± 404
Quick feed continuous	1490 ± 453
Slow feed periodical	895 ±380
Quick feed periodical	1590 ± 387
Slow faeces	< 1
Quick faeces	<1

Carbon concentration

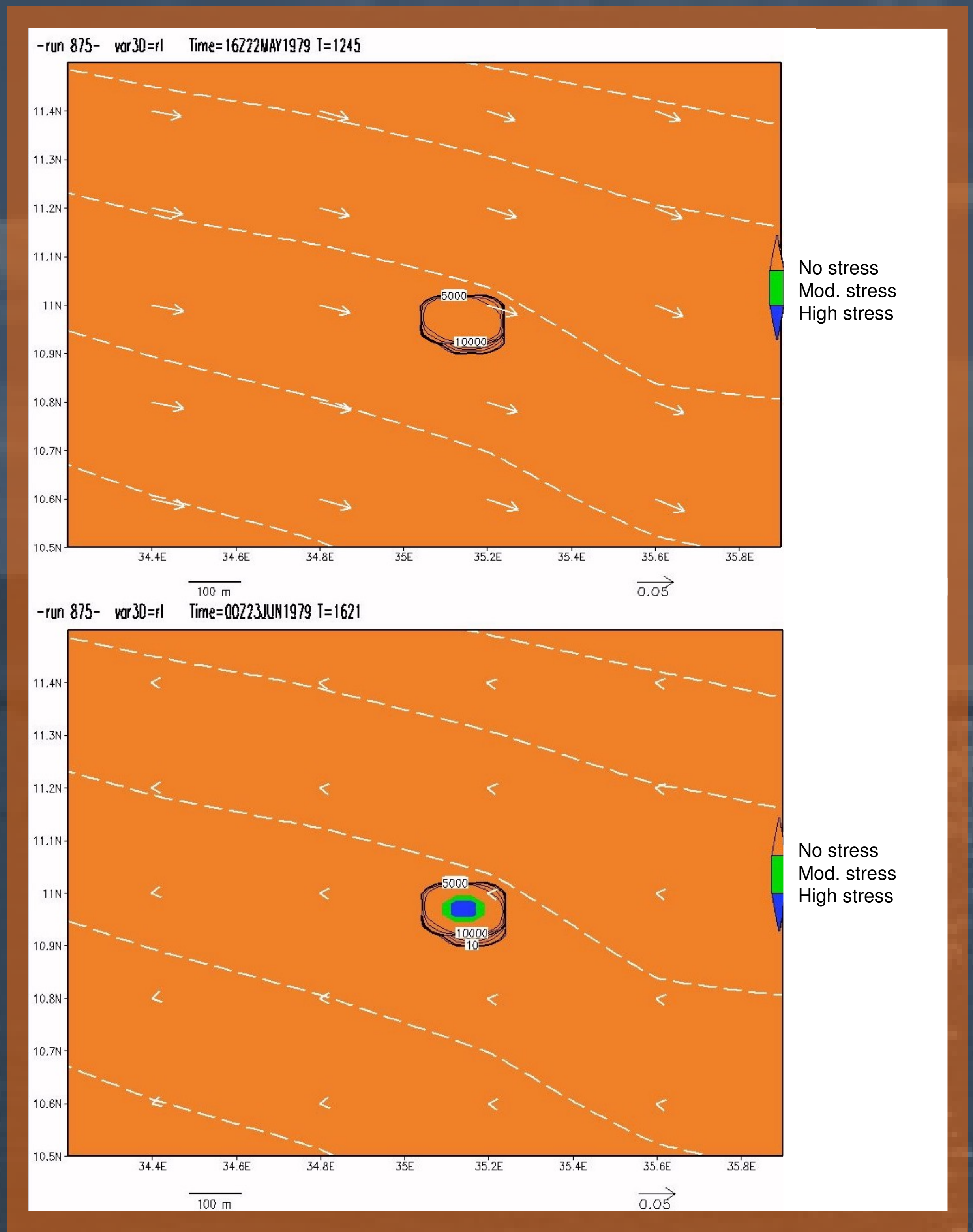


Carbon concentration



Cold season forms highest concentration, warm season lowest

Index of impact



current intensification

⇔

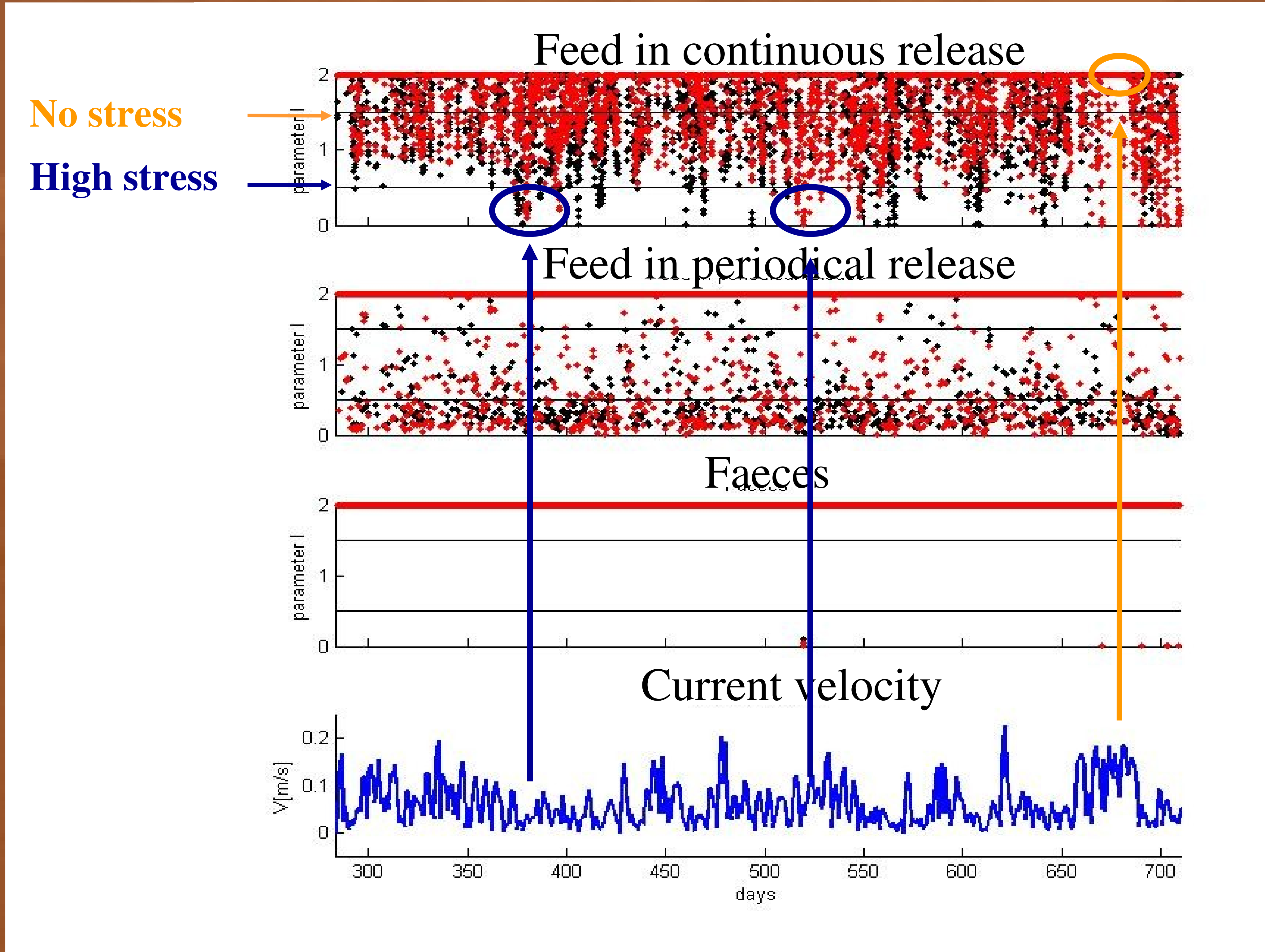
low stress condition

weak current

⇔

high stress condition

Index of impact



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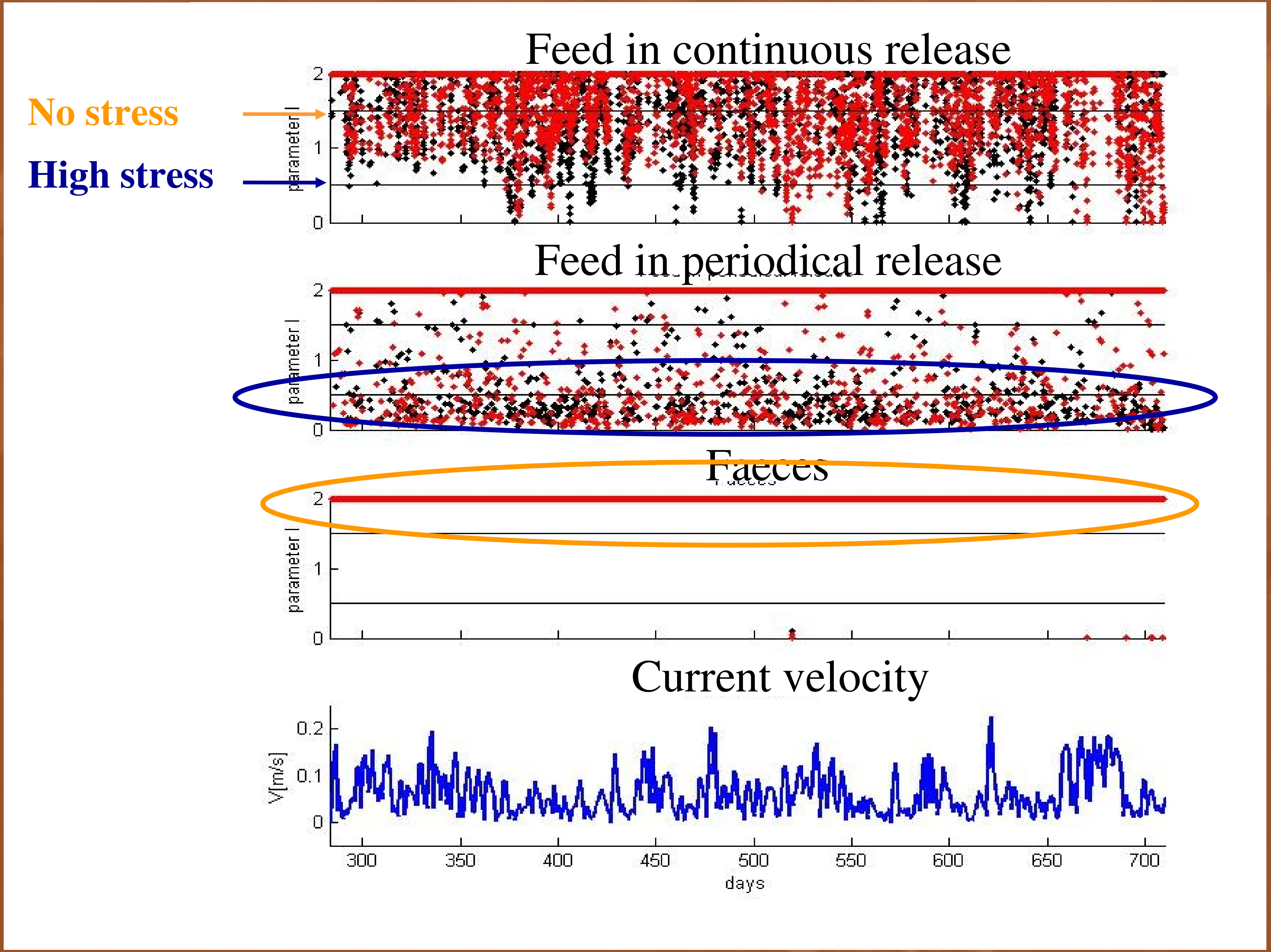

Index of impact

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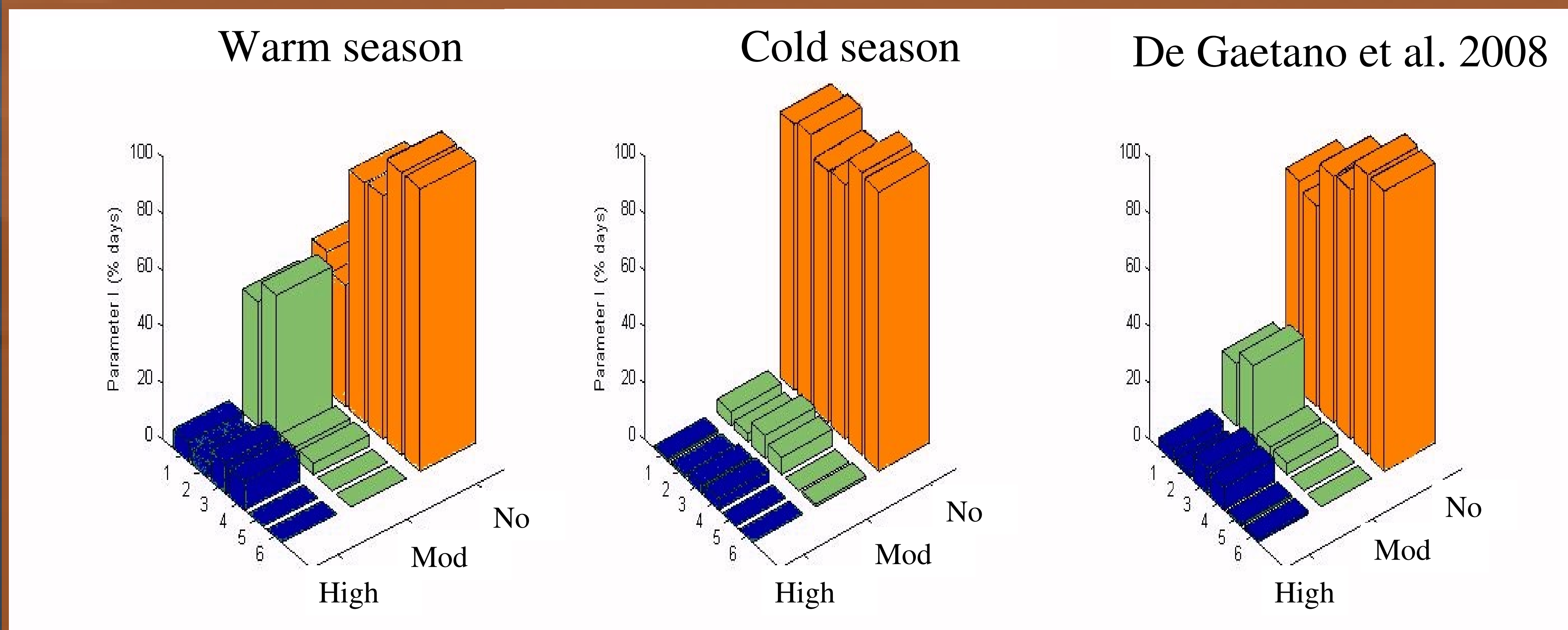
Warm season: maximum occurrence of moderate and high stress conditions

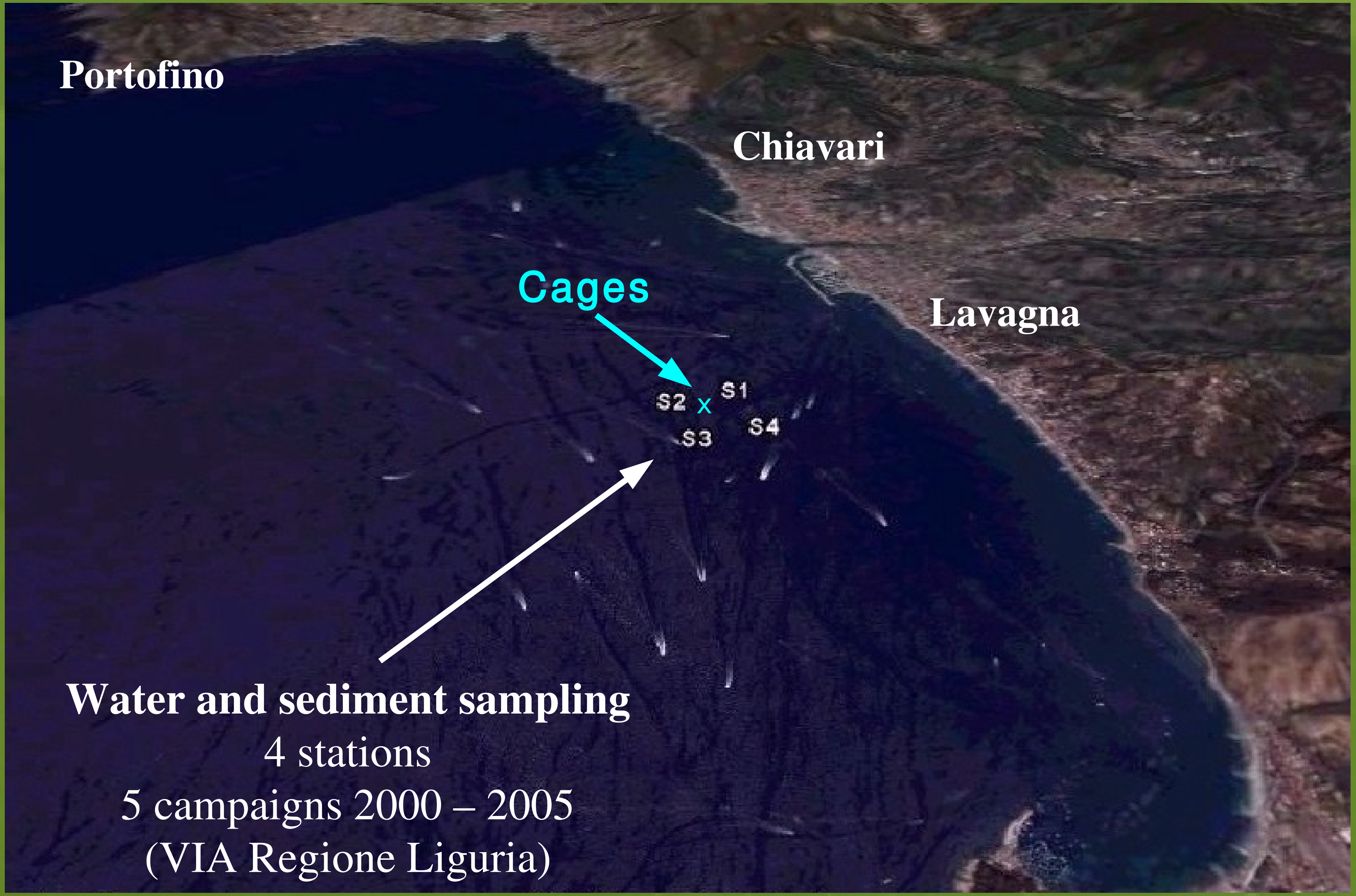


1-slow feed continuous
4-quick feed periodical

2-quick feed continuous
5-slow faeces

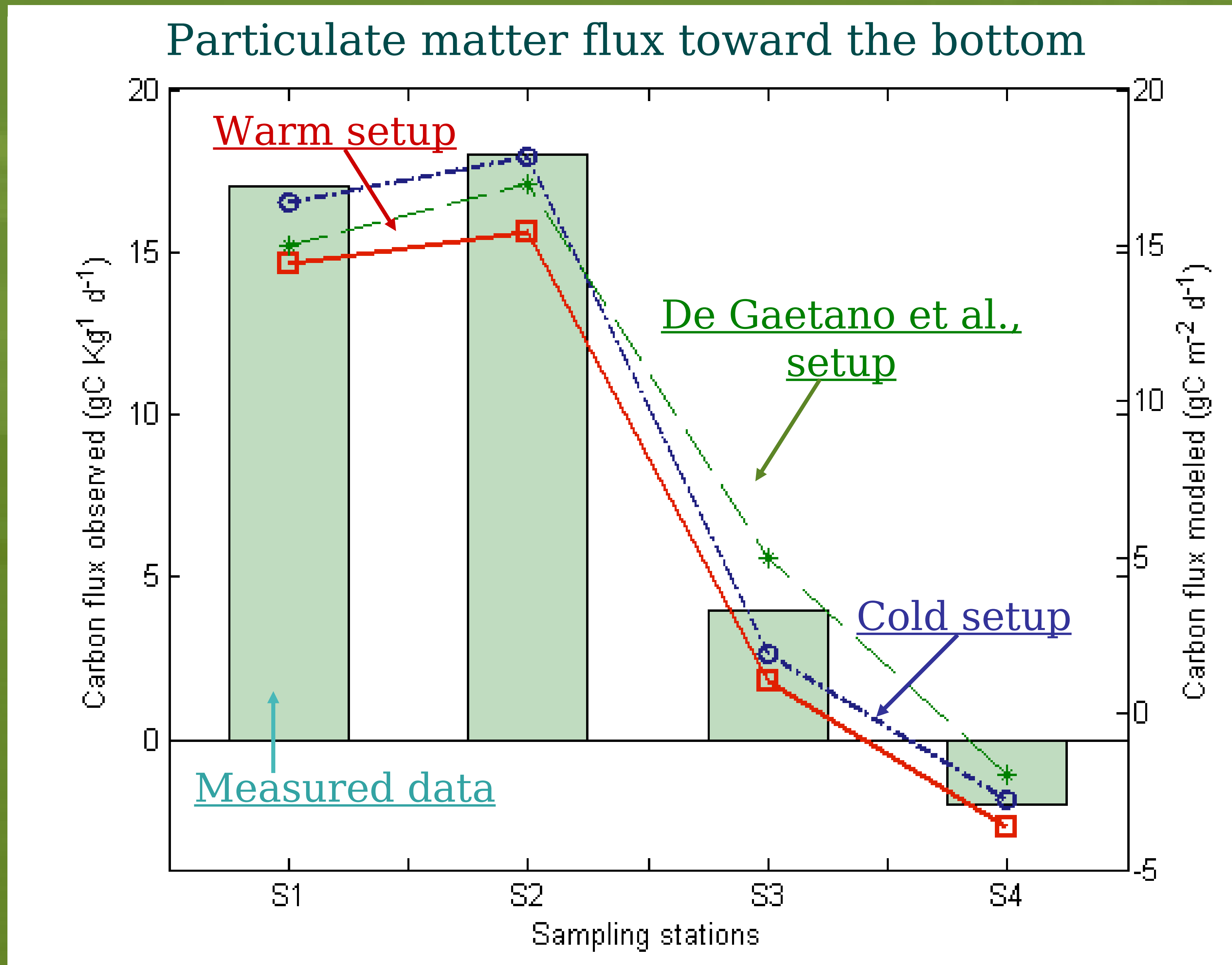
3-slow feed periodical
6-quick faeces

Model Validation



Water and sediment sampling
4 stations
5 campaigns 2000 – 2005
(VIA Regione Liguria)

Model Validation



Conclusions

Max C concentration and high stress condition due to feed released in periodical mode

Benthic metabolism depends on season

Warm season: maximum impact while minimum area and concentration

Better prediction capability

Outlooks

Sampling campaign for benthic metabolism dependence on water temperature

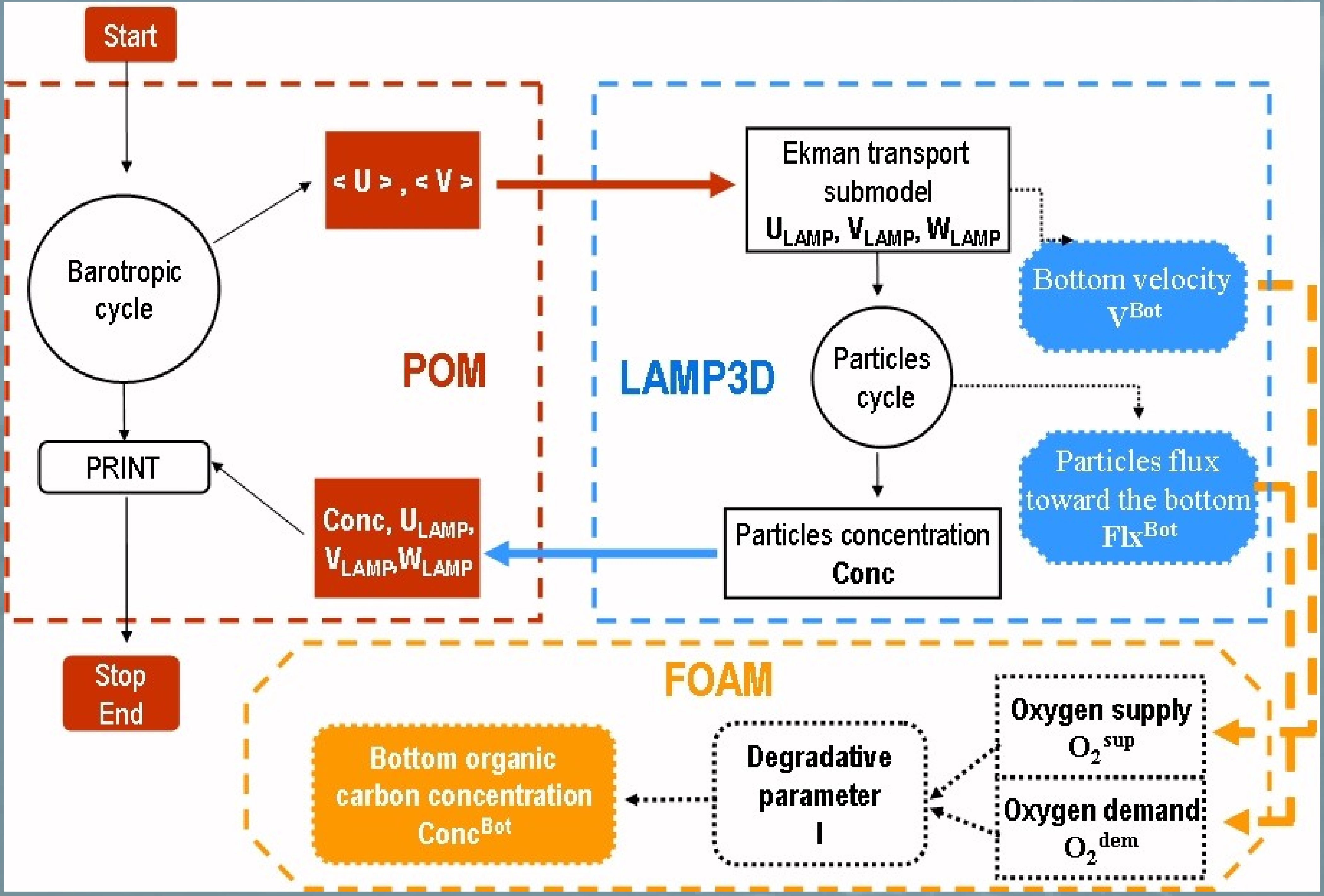
Improve reliability of hydrodynamic model

THANKS YOU

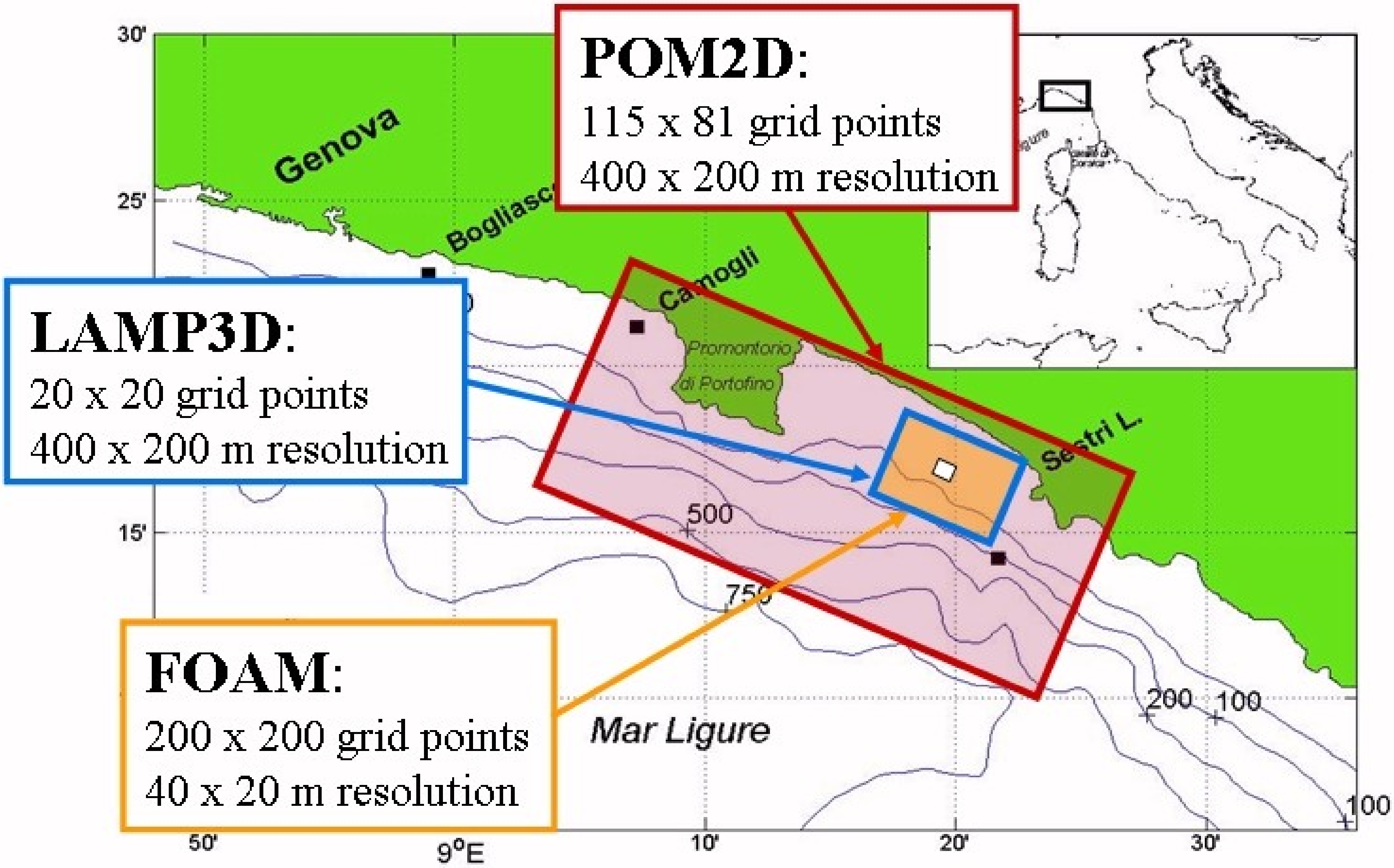
Patrizia De Gaetano

POM-LAMP3D-FOAM
coupled model

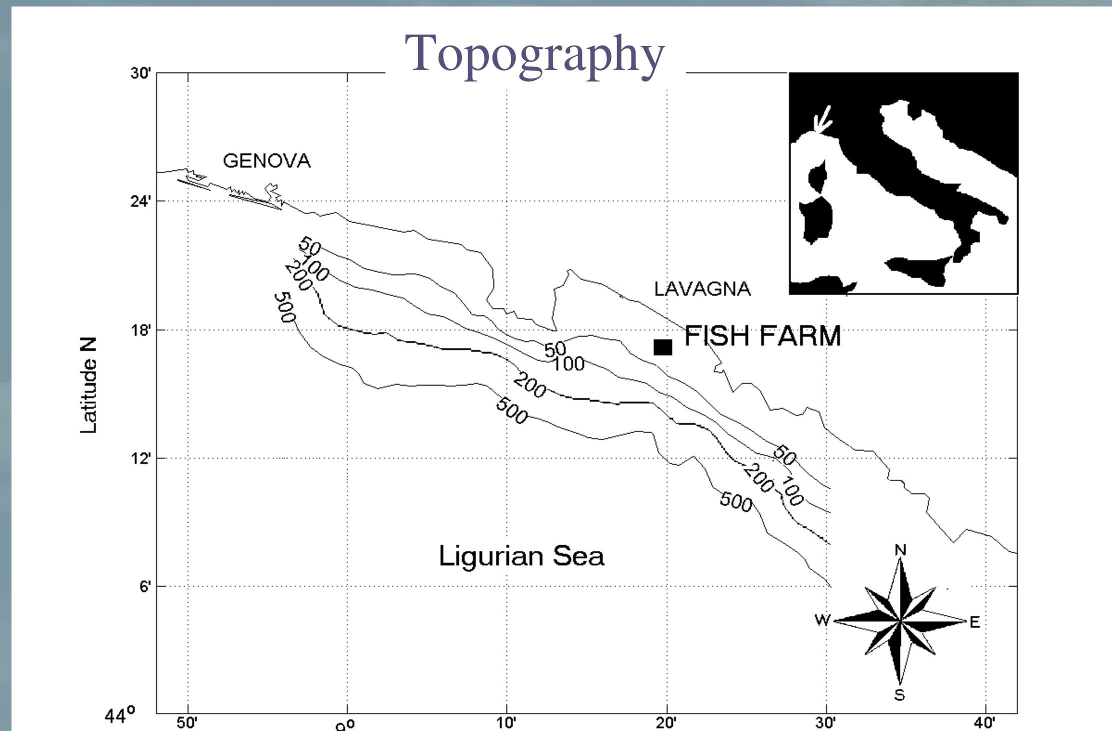
Introduction
Model Setup
Application
Results
Conclusion

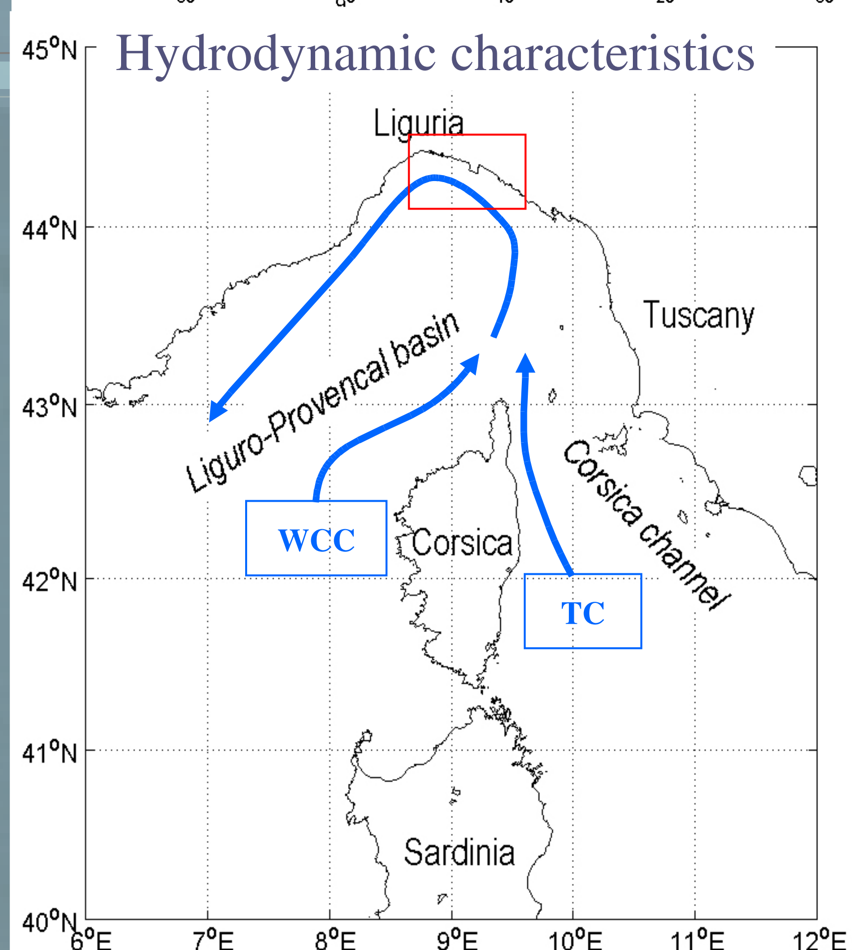


Numerical grids and Nesting

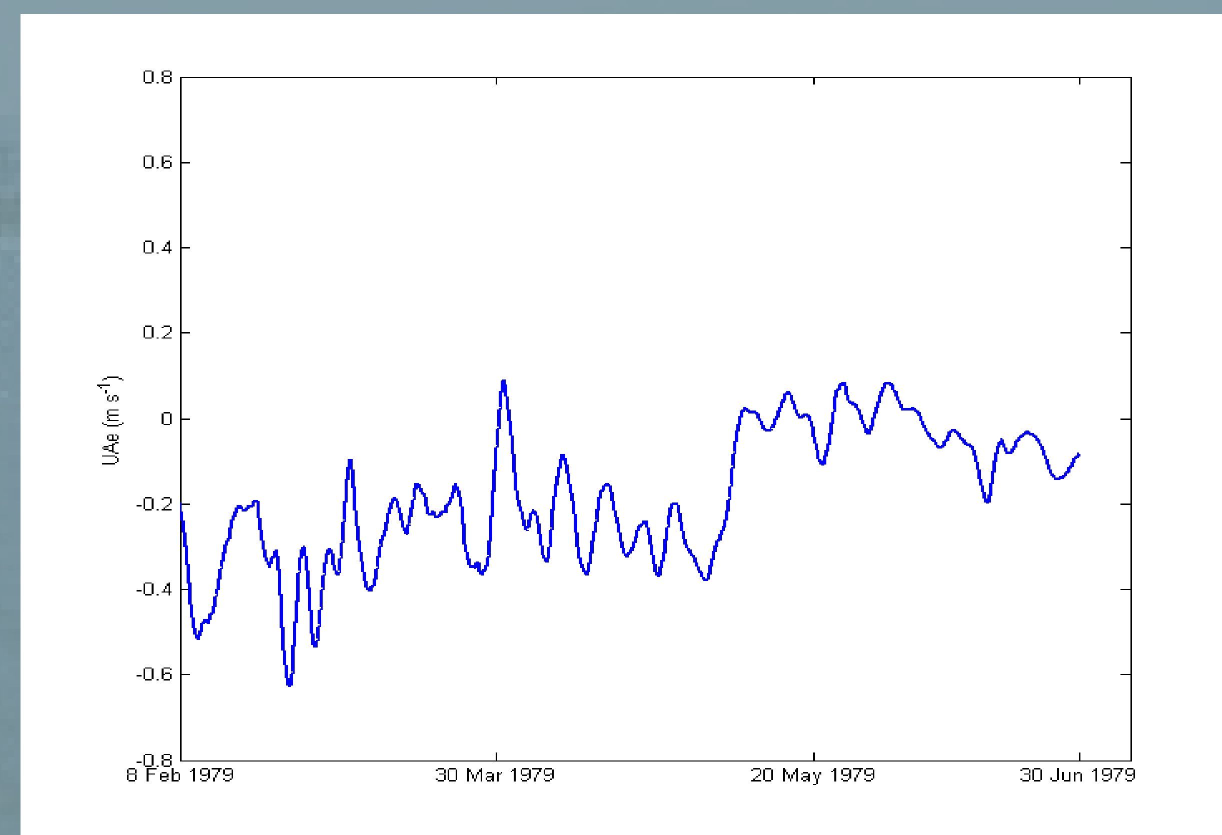


Studied Area

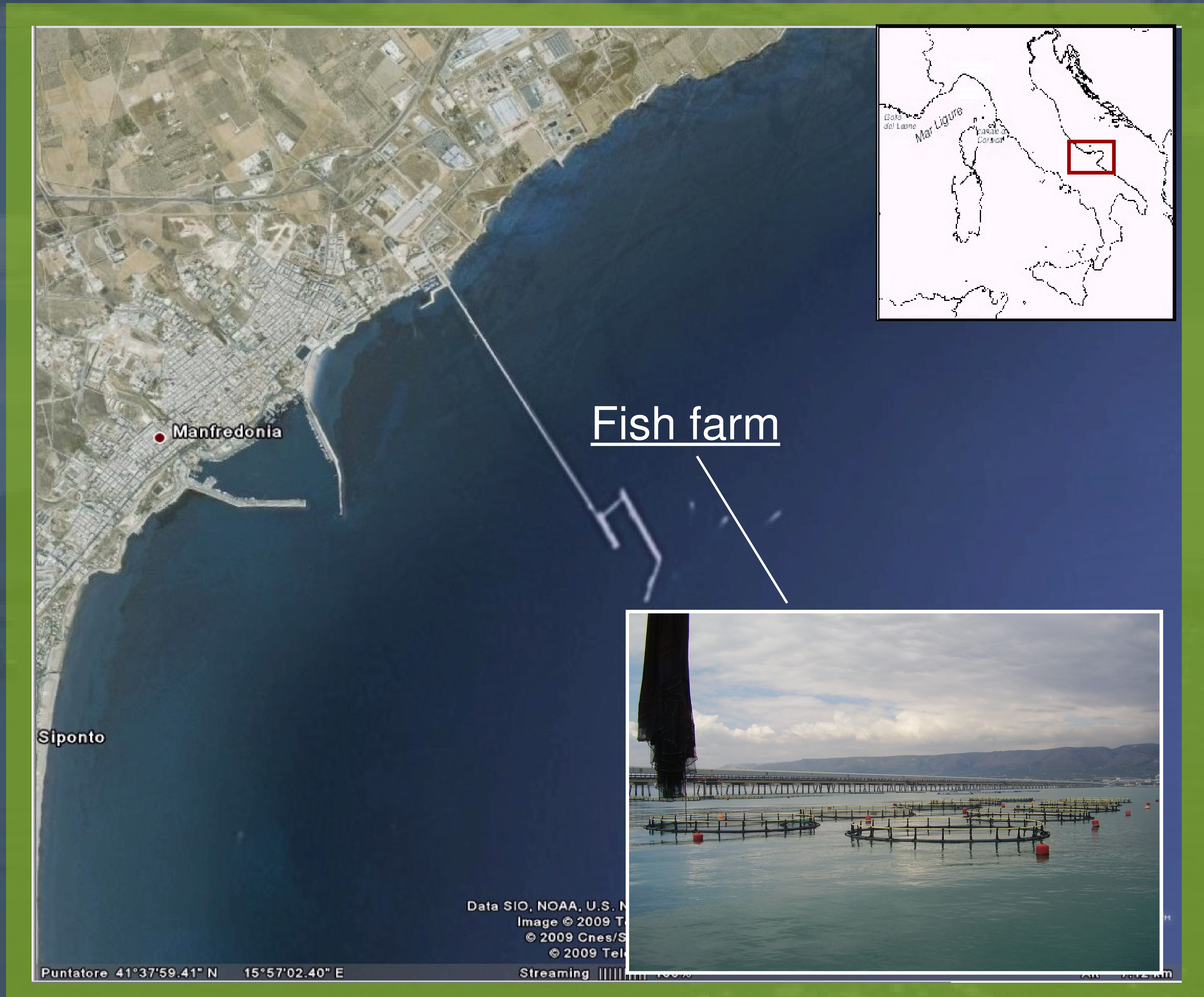




Forcing:
real historic current-meter data

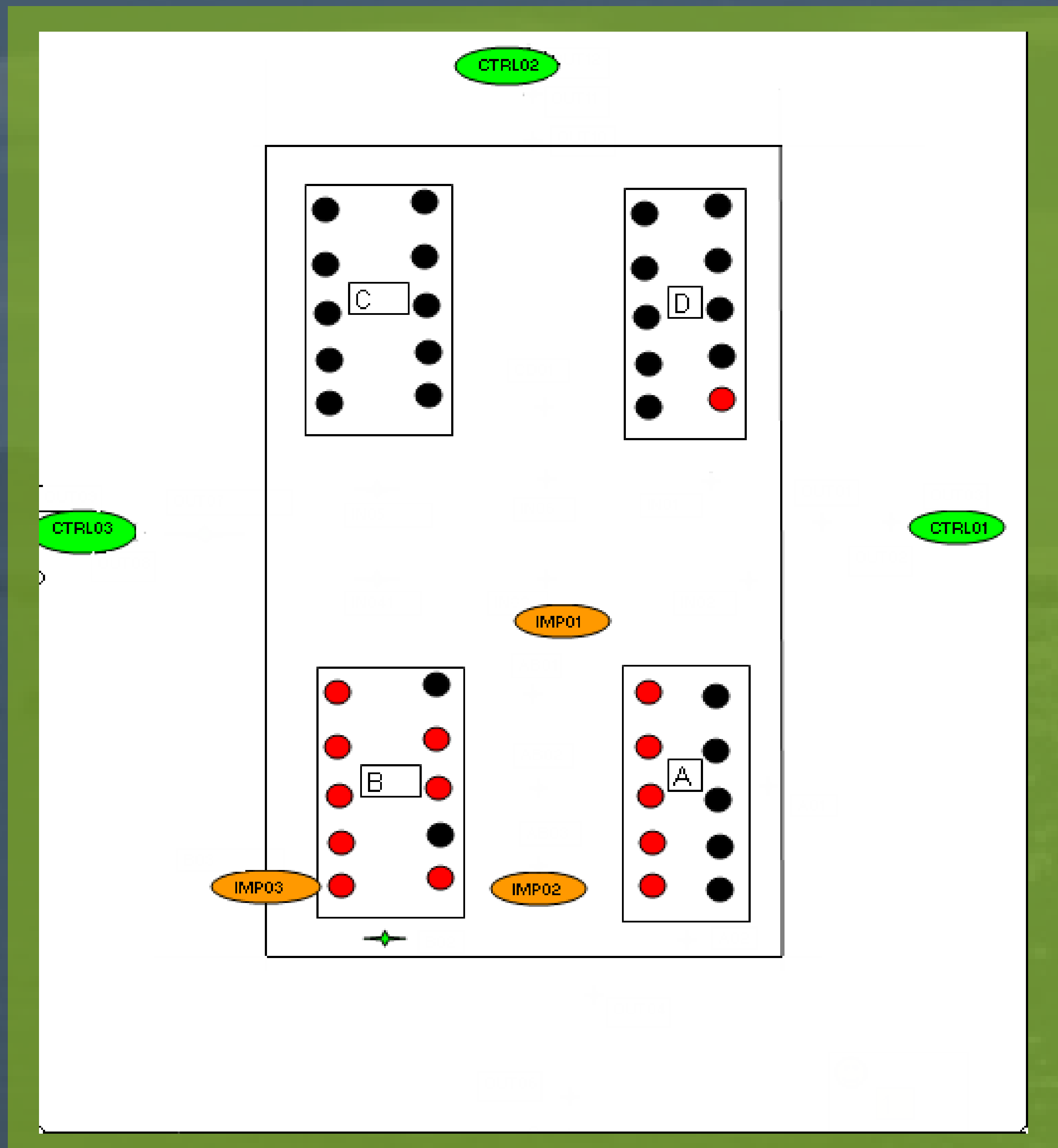


Sampling campaigns



Sampling campaigns

May 2006 pre-survey activity: 6 sampling stations



July and October 2006
- measurements of:

- C flux toward the sediment
- O_2 flux
- total inorganic C flux

POM

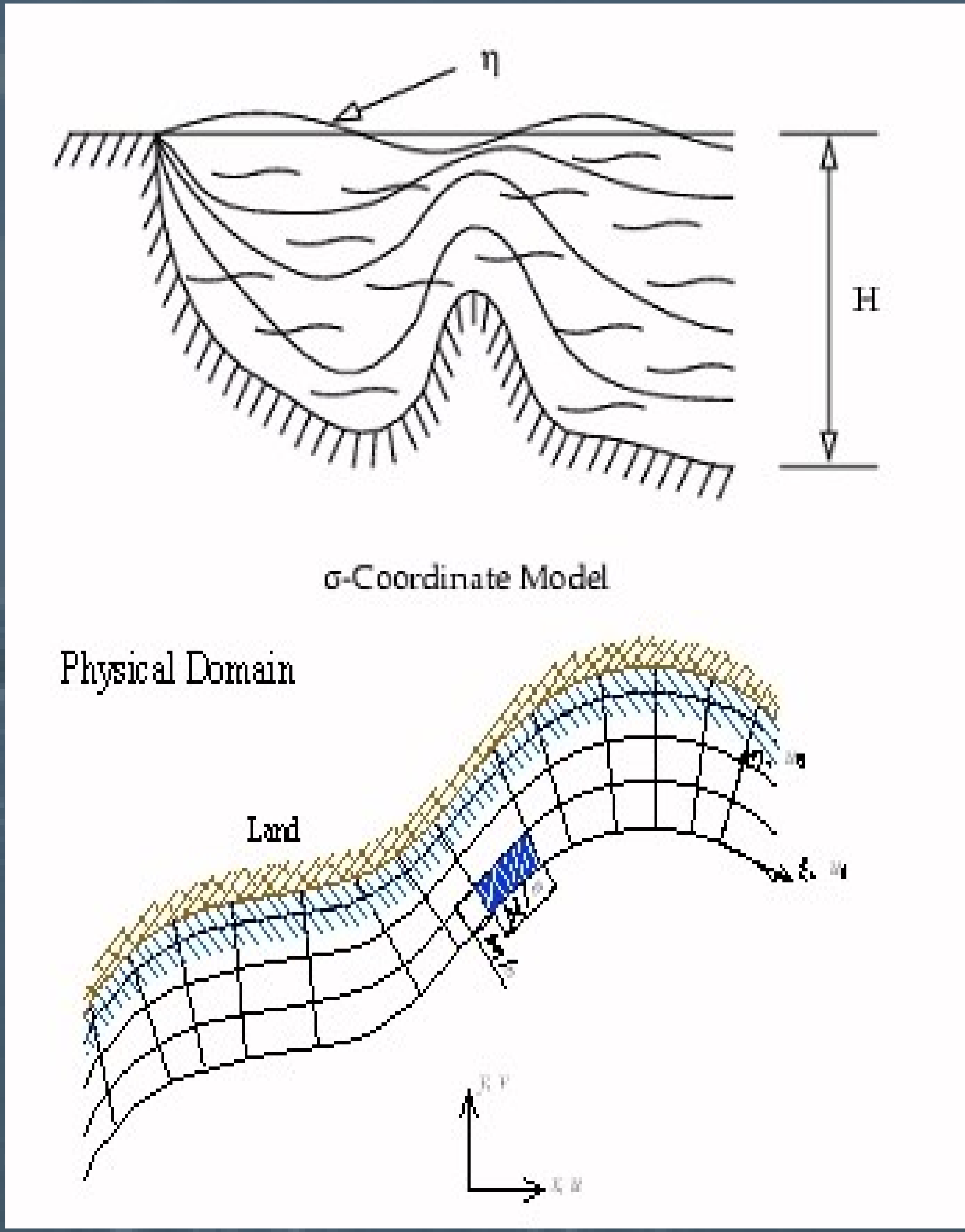
Ocean circulation model solves the hydrostatic primitive equations

Vertical sigma-coordinate

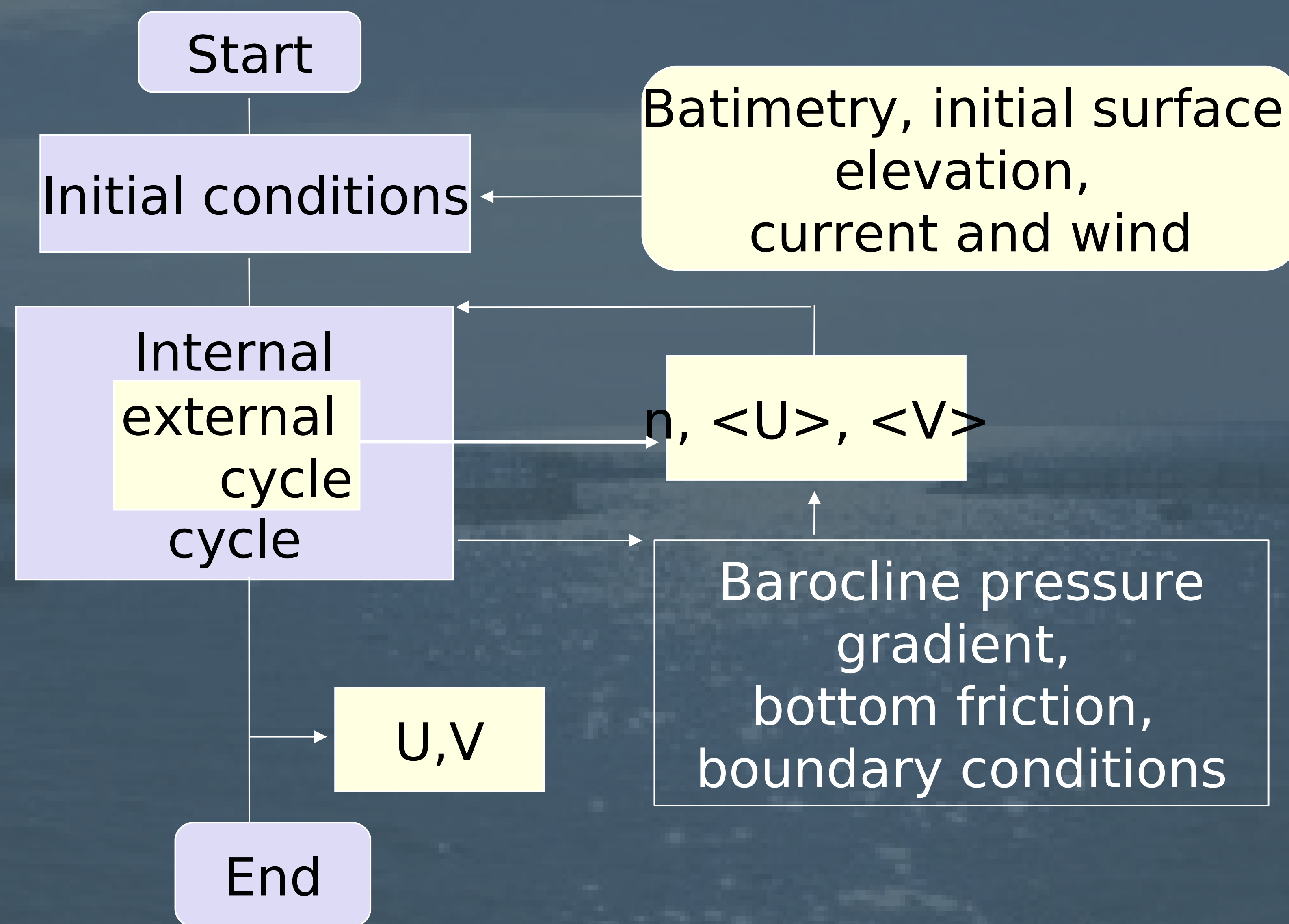
Curvilinear horizontal coordinates

Time-split scheme:
barotropic circulation
(external mode) slower time step

baroclinic component
(internal mode) faster time step



POM


Start
Initial conditions
Batimetry, initial surface elevation, current and wind
Internal
external cycle
cycle
n, <U>, <V>
Barocline pressure gradient, bottom friction, boundary conditions
U,V
End

Bentich State

Three level of organic enrichment based on

Respiratory Quotient

$$RQ = \frac{|CO_{2\ produced}|}{|O_{2\ produced}|}$$

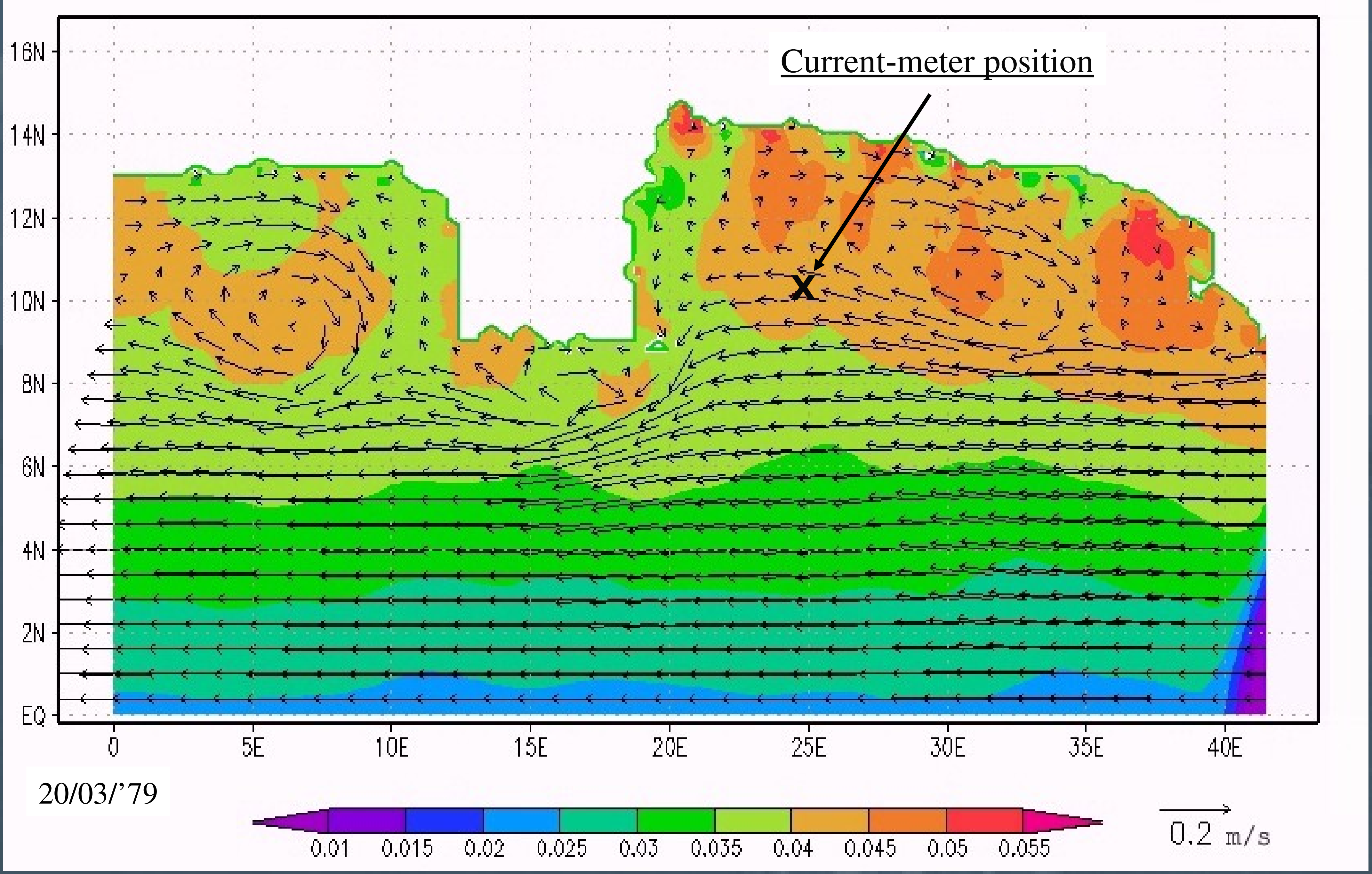
Dilly, 2003
Hargrave, 2008

RQ < 0.8 ⇨ limited organic load

0.8 < RQ < 1.2 ⇨ moderate organic load

RQ > 1.2 ⇨ elevate organic load

Circulation model - validation



Circulation model - validation

5 linked simulation for simulate a longer period

Current measurements

Winter average (std)	Spring average (std)	Summer average (std)	Autumn average (std)	Annual average (std)
0.066 (0.057)	0.075 (0.065)	0.063 (0.052)	0.070 (0.052)	0.069 (0.057)

Model output

	Winter average (std)	Spring average (std)	Summer average (std)	Autumn average (std)	Overall average (std)
1st cycle	0.076 (0.051)	0.103 (0.084)	- -	- -	0.088 (0.047)
5th cycle	0.059 (0.034)	0.082 (0.066)	- -	- -	0.057 (0.034)
3th $\rightarrow$ 5th cycles	0.064 (0.042)	0.078 (0.050)	- -	- -	0.061 (0.034)

⇩

neglect the first 2 cycles to reduce the sensitivity to initial conditions