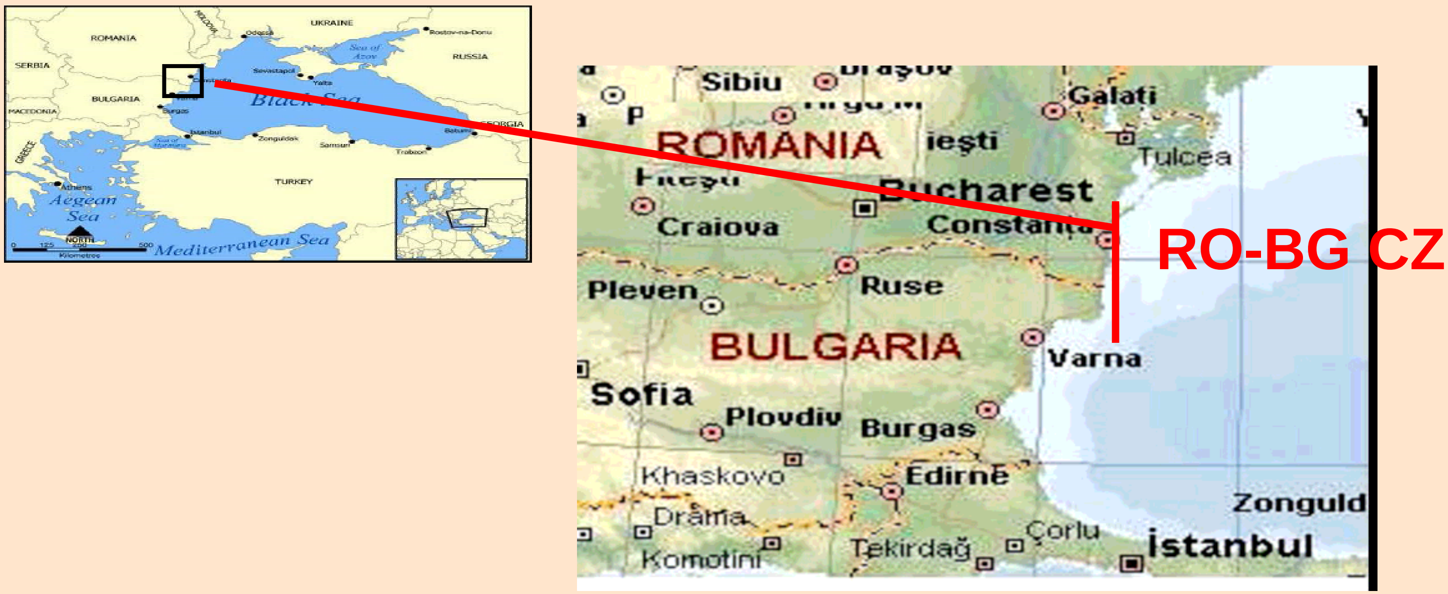
SSA 18: Danube Delta–Romanian–Bulgarian Black Sea CZ

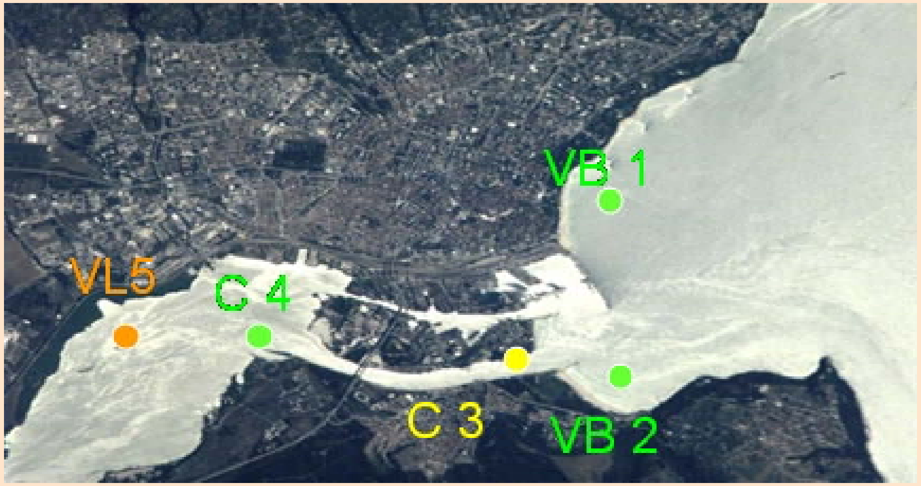


Danube Delta National Institute for Research and Development, Tulcea, Romania

Institute of Oceanology, Bulgarian Academy of Sciences, Varna, Bulgaria

Institute for Environment & Sustainability, GEM Unit, EC DG-JRC, Ispra, Italy

VARNA BAY



How to maintain a good quality of bathing waters in Varna Bay?

VARNA BAY

Environmental Component:

-the environmental **risk imposed by meteorology** contributing to “environment disaster condition” versus improvement/rebuilt of WWTP in the area;

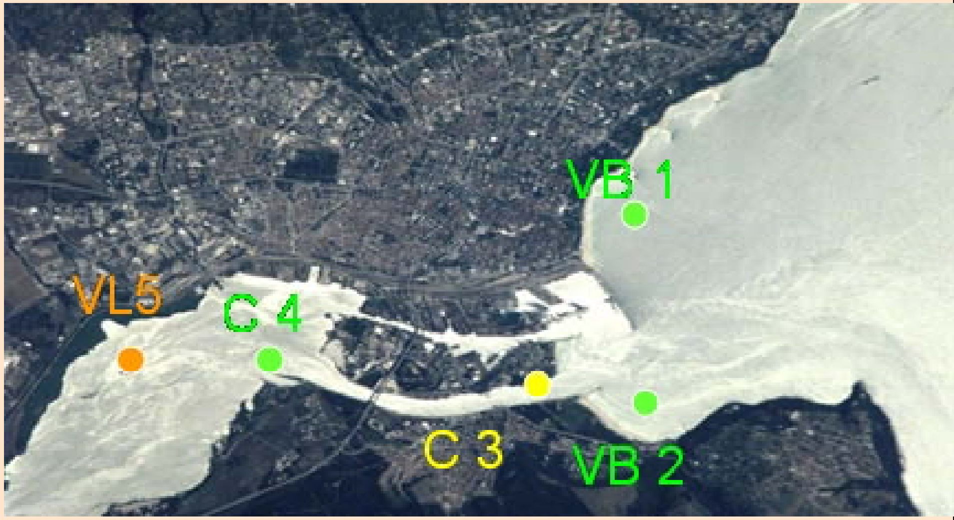
- **sewage** system and **landfills improvement** versus **improvement**/ rebuild of **WWTP**

Economic component:

How the **deterioration** of the Varna beach coastal area (WQ) will influence the **tourist economy** (tourist visits reduction/recreational demand)−economic losses/ investment cost for reaching/maintaining “good” WQ

Social component:

Public perception/demand (aesthetic value, willingness to pay for WQ improvement/”good” ecological status maintenance



EXTEND MODEL
Varna Bay
SSA-18
ECOLOGICAL COMPONENT

Eleonora Racheva, Snejana Moncheva- Institute of Oceanology, Varna

Lyudmila Kamburska- JRC, Ispra

Thomas Hopkins- IACM, CNR, Naples

MAIN GOAL

How to maintain a good quality of bathing waters in Varna Bay?

Scenarios :

- **Comparative assessment (quantification) of the environmental risk imposed by meteorology contributing to "environment disaster condition" versus improvement/rebuilt of WWTP in the area;**
- **Comparative assessment of Sewage System and landfills (rain storage facilities) improvement versus improvement/rebuild of WWTP**

The scenarios should distinguish environmental risk factor that will drive the system by including it in an "urban waste water metabolism "component

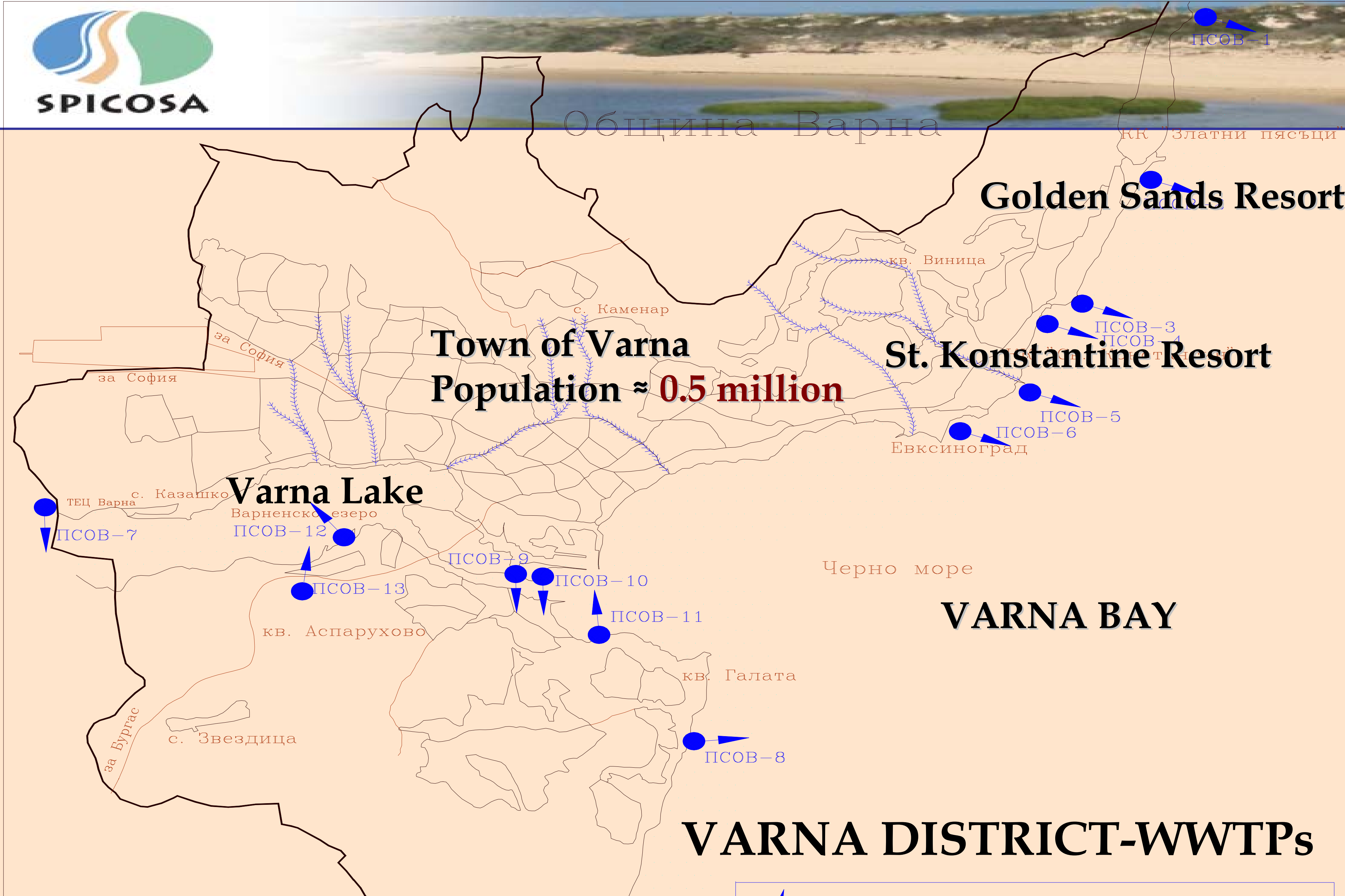
OBJECTIVES

To determine the influence of the WWTP nutrient loads along the resorts (during the high season) over the quality of the marine environment;

To answer the question if the primary productivity is driven by the excess of nutrients directly released in the system from WWTPs (frequency and duration of blooms), and if so, how much the reconstruction of the WWTP along the resorts, through reduction of nutrient loads, will contribute to improvement of the water quality- reducing phytoplankton blooms and related to it the Secchi depth variability;

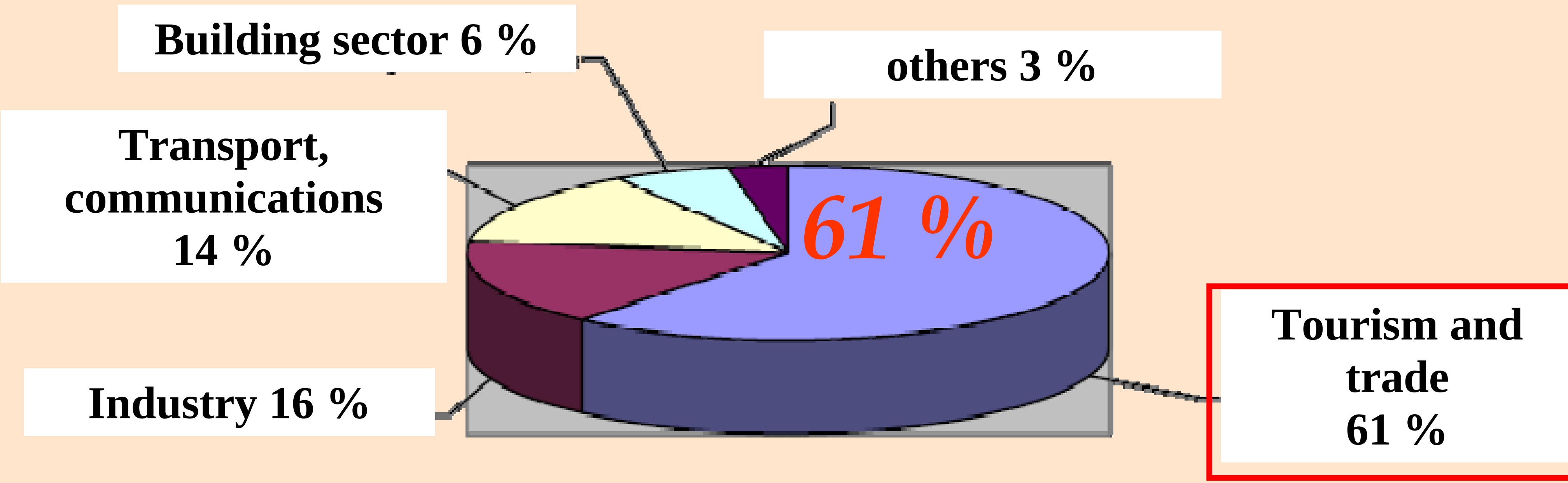
To estimate the contribution of TSS loads from land based flow, mainly after storm/rain to the decrease of the water transparency

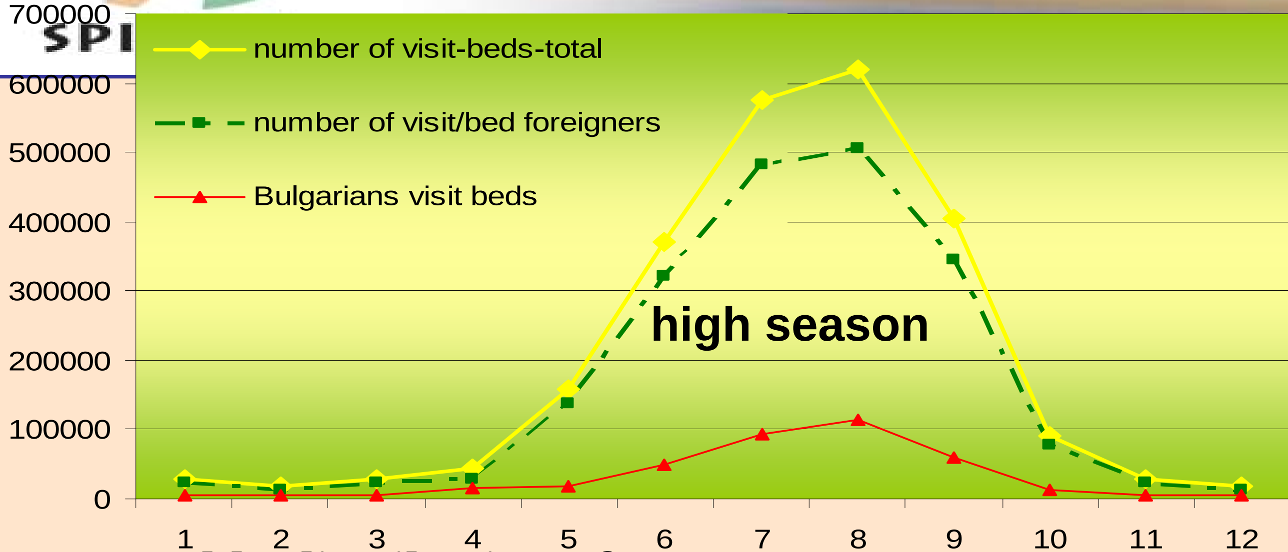
VARNA DISTRICT-WWTPs



– Пречиствателна станция за отпа...

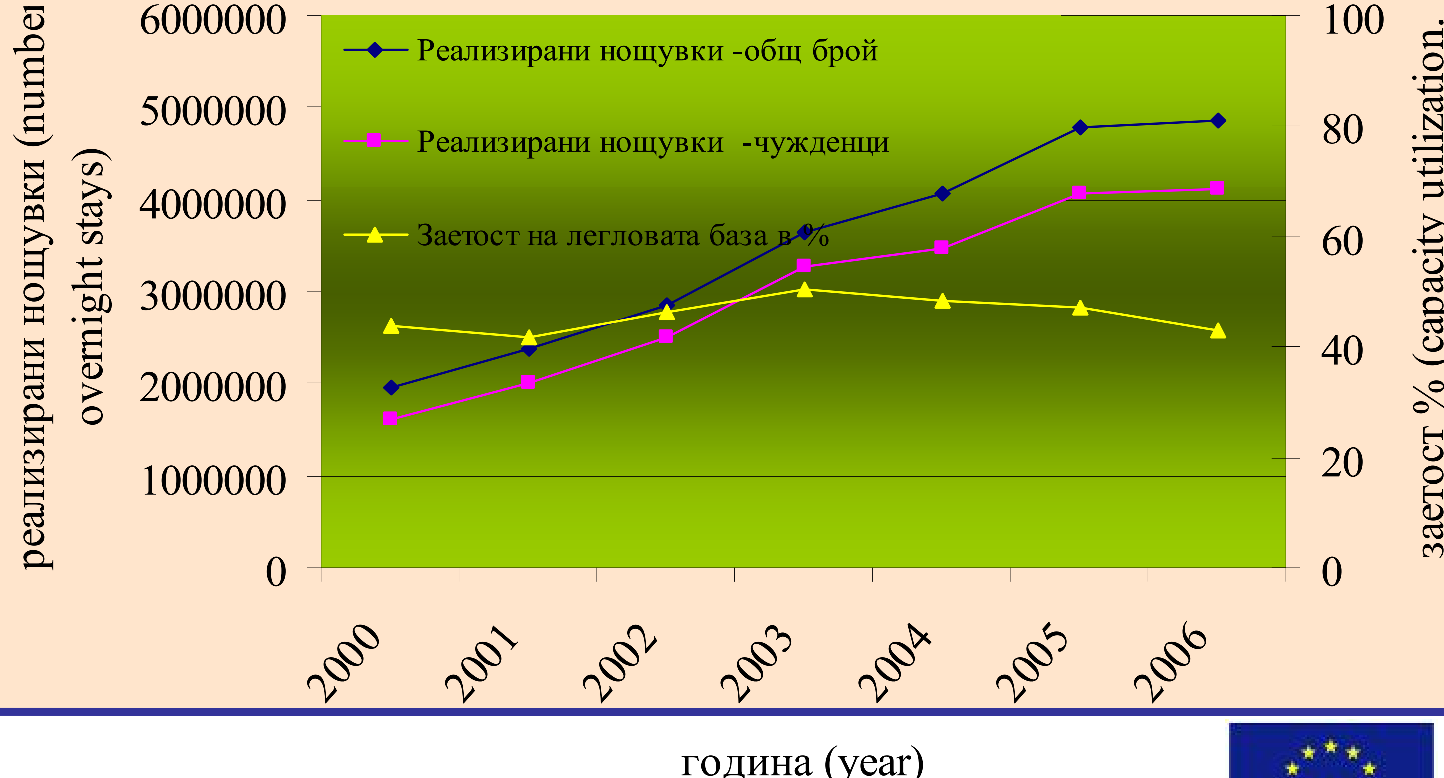
NET INCOME BY SECTORS -VARNA DISTRICT





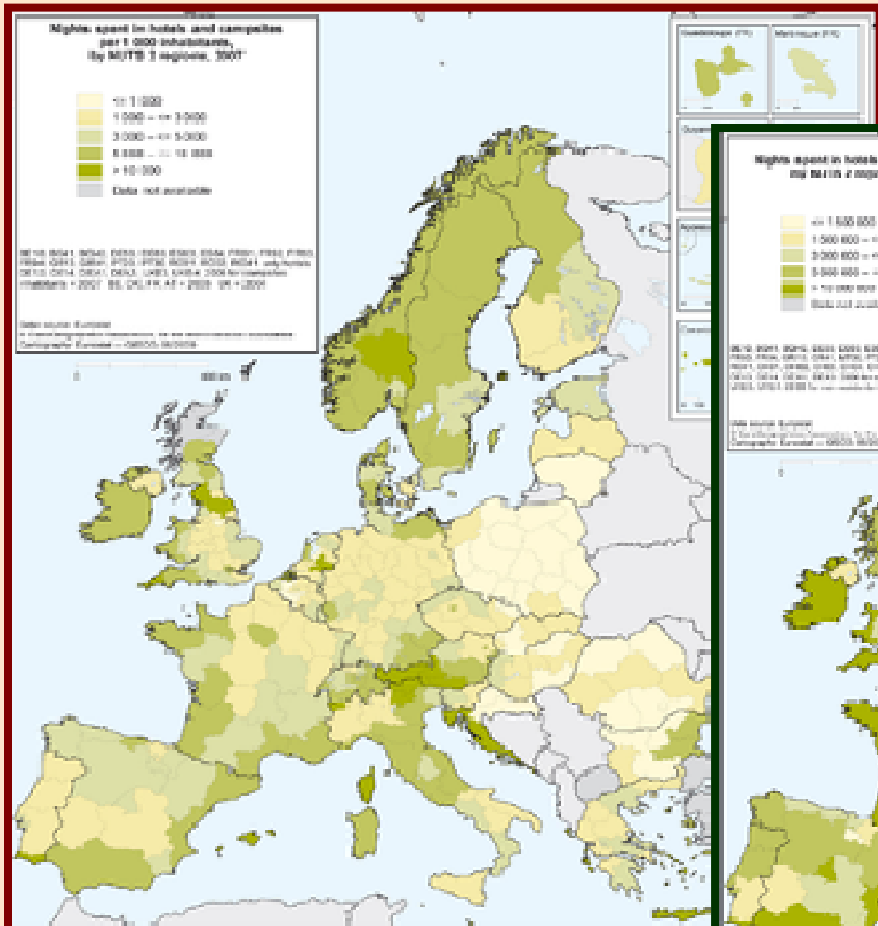
Monthly distribution of tourists in 2001

Annual growth of tourists in 2001-2006

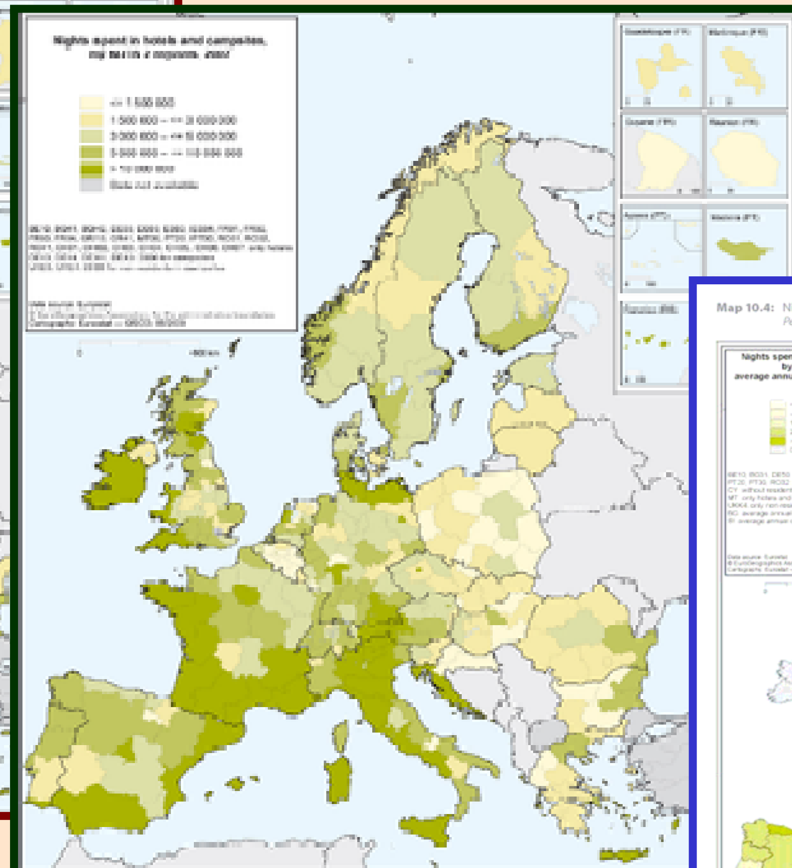


Trends in tourism 2000–2006

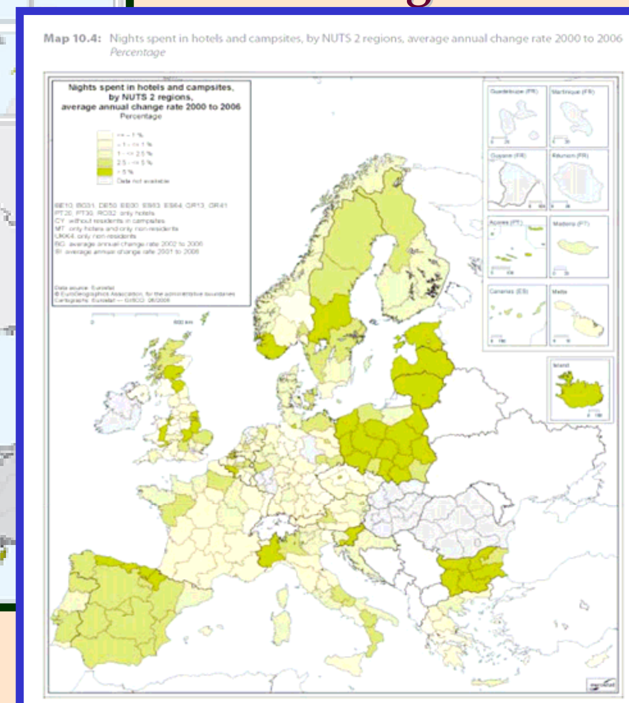
Varna region 2.5 – 5 %
BG> 5 % /year
EU-27 average - 1.2 %



Nights spent in hotels per 1000 inhabitants by regions, 2007



Nights spent in hotels by regions 2007

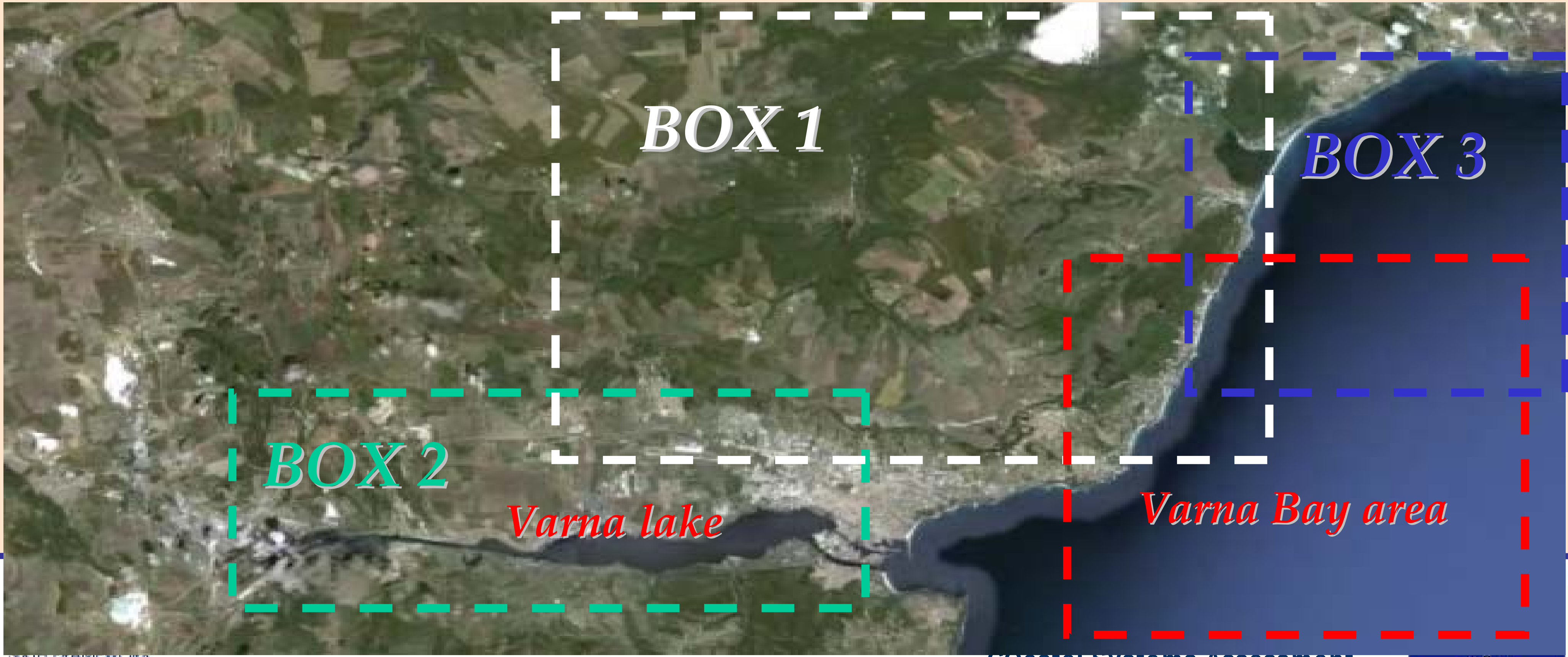


BOX 2 - nutrients load from the Provadiiska-Beloslav lake-Varna lake (chemical industry and the Varna city WWTP located in the Varna lake area) is represented by the indirect input through the channels. The approximations here are that the two layers in VL are mixed, but a salinity gradient persists because of the Fresh Water input to the surface layer and the more salty incoming water to the bottom layer

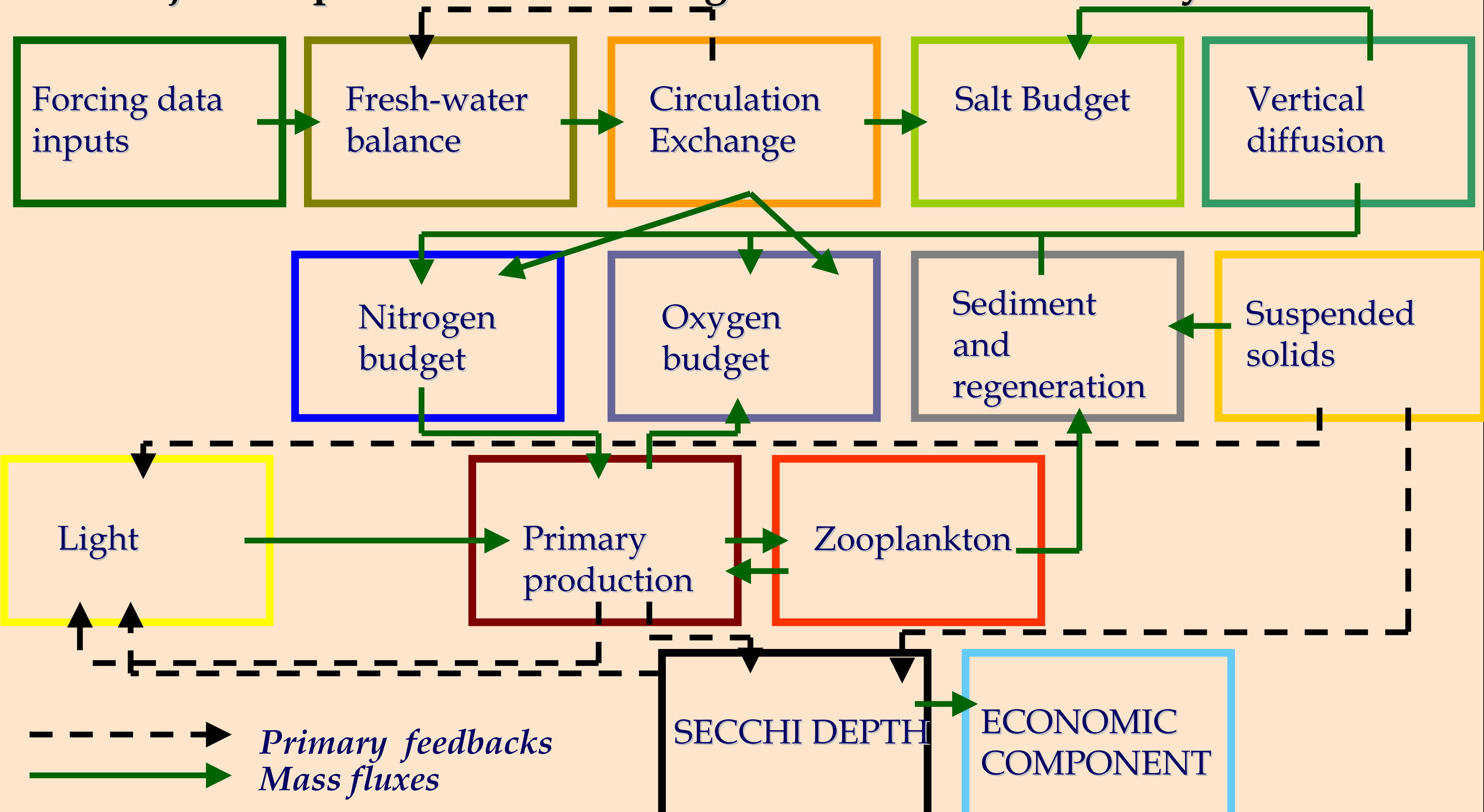
BOX 1 land based loads (mainly from WWTPs point sources) and non –point sources (land based flow, mainly after storm/rain and the untreated domestic waste-waters from households and activities not connected to the Sewage system) bringing dissolved nutrients and TSS

BOX 3 –Exchange with open Black Sea area - Danube influence (lower salinity / high nutrients or phytoplankton bloom innoculum)

VARNA BAY BASIN – VIRTUAL SYSTEM



Major components of the Ecological model for Varna Bay



MODEL

The model is driven by meteorological data inputs, light regime conditions, volume and salinity exchange with Varna lake (Sub-model), Open Black Sea, Coastal current (wind stress).

Salinity results from the Varna lake model are used to drive the exchange with Varna Bay

The land runoff and Nutrient loadings are calculated using available observations of these and the Varna lake input is directly imposed as measured values from the channel (Varna Bay-Varna Lake).

The modeled values of the phytoplankton community (2 phytoplankton groups) are compared with observed data for the period 2001.

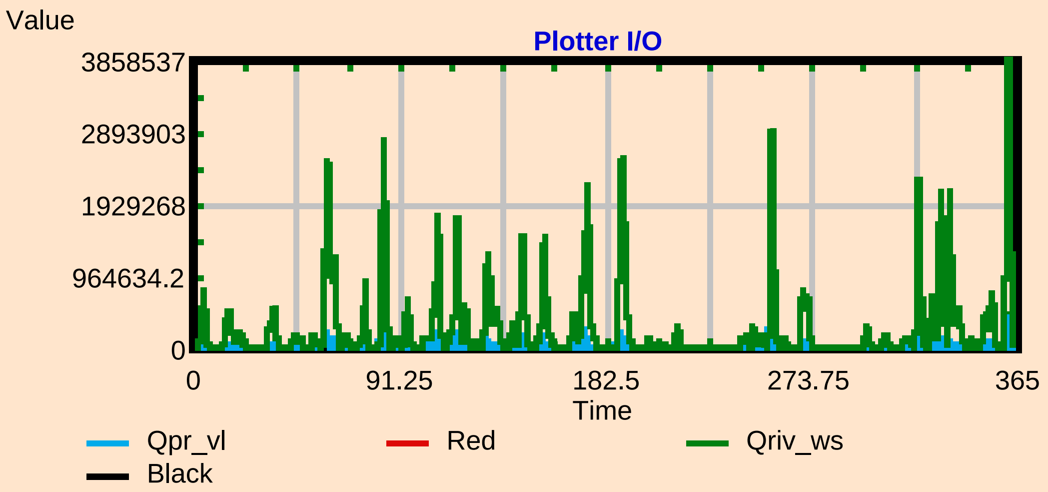
VARNA LAKE SUBMODEL

FORCING DATA INPUTS:
Temp. air; Humidity; Temp. water; wind speed; Rain; Salinity_in from Varna bay.

FRESHWATER BALANCE:
The freshwater balance represents the sum of the rain on Varna Lake surface, the land runoff, and the evaporation from the surface. The evaporation is calculated using the water-vapor pressure and temperature differences, and the surface wind. The runoff is estimated.

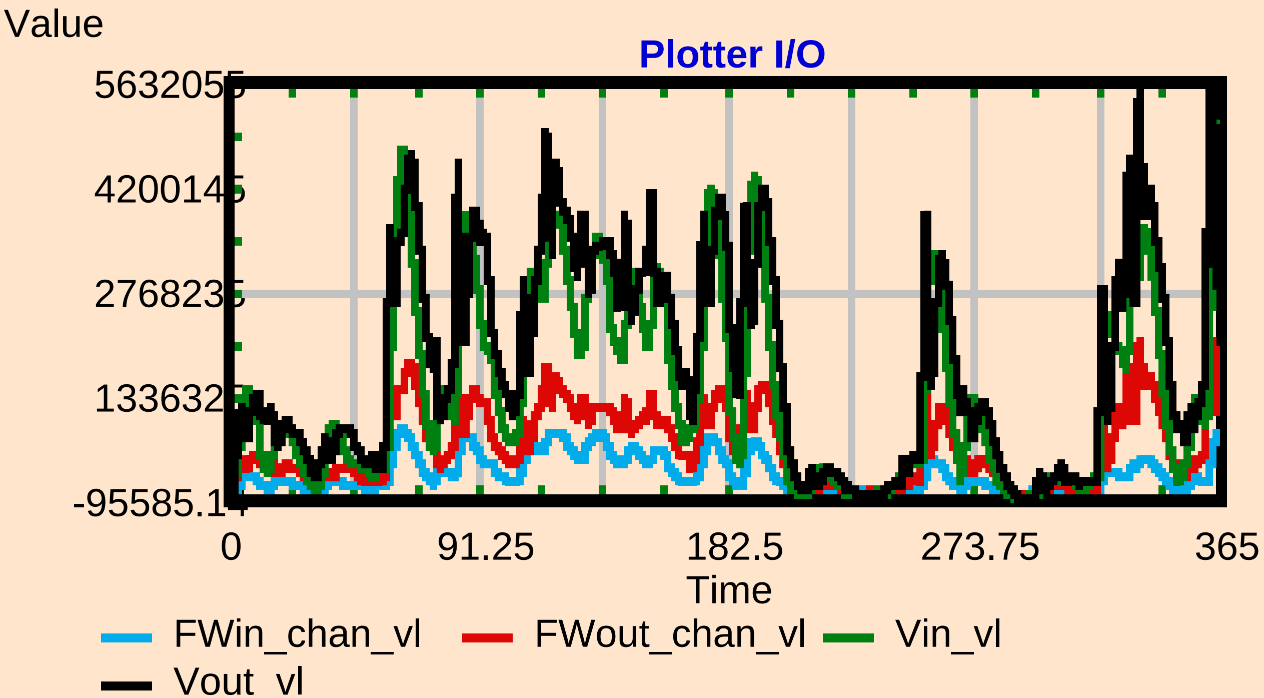
Rain on Varna Lake (m3/d)
Lake Watershed Runoff (m3/d)
Lake Local Runoff (m3/d)
Peripheral land runoff (m3/d)

FRESH WATER BALANCE



CIRCULATION

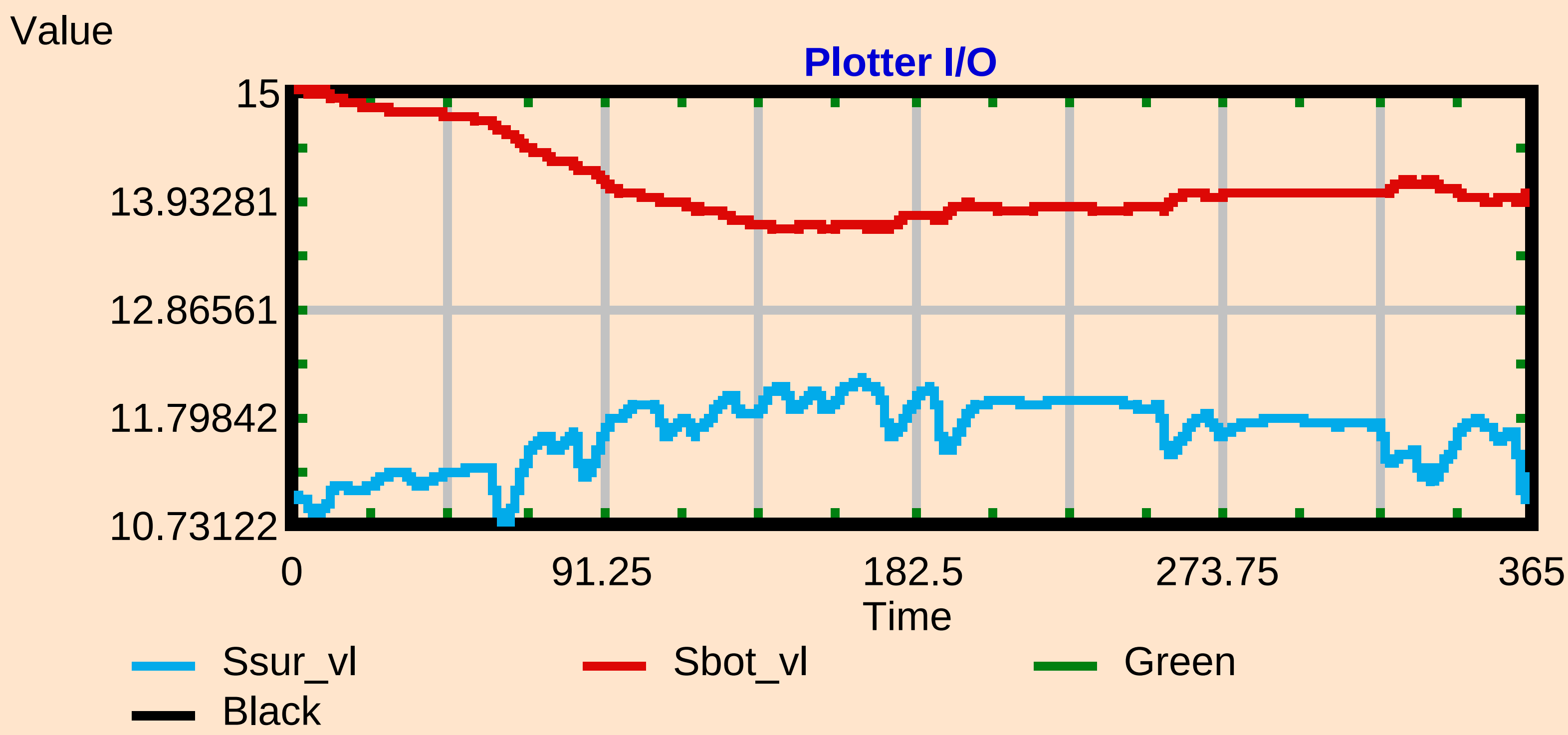
An approximation of the Thermohaline Exchange Method (*TEM,Hopkins,1999*) is used to derive the formulas used in this panel. The exchange can be expressed as a draining relation in which the inter-basin pressure gradients determine the exchange, i.e. the exchange is proportional to the force that creates it



- A diffusion parameter controls the salinity difference between the layers.
- A constant parameter (alpha) controls the speed of the thermohaline circulation, which acts to bring in more salt.
- A adjustment parameter (FWfrac) controls the amount of freshwater entering the system.

SALT BUDGET

The total salt in the surface and bottom layers are calculated by keeping a running account of the amount of salt brought in to the bottom layer, that diffused up to the upper layer.



Bottom salinity (promiles)

Surface salinity (promiles)

VARNA BAY MODEL

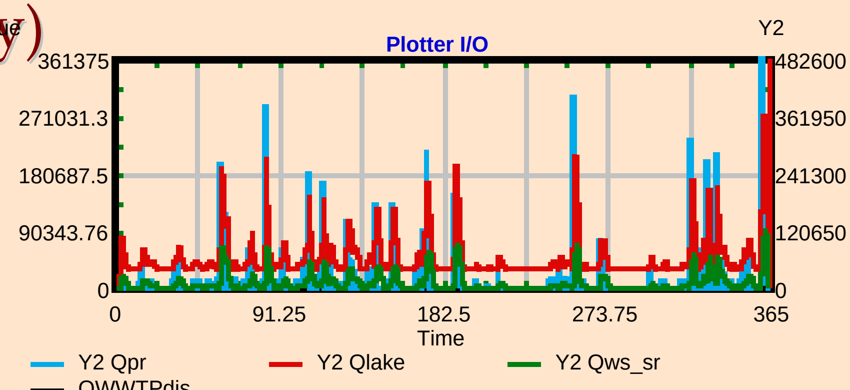
FORCING DATA INPUTS:

Temp. air; Humidity; Temp. water; wind speed; wind direction; Rain; Salinity_in from Varna lake.

FRESHWATER BALANCE:

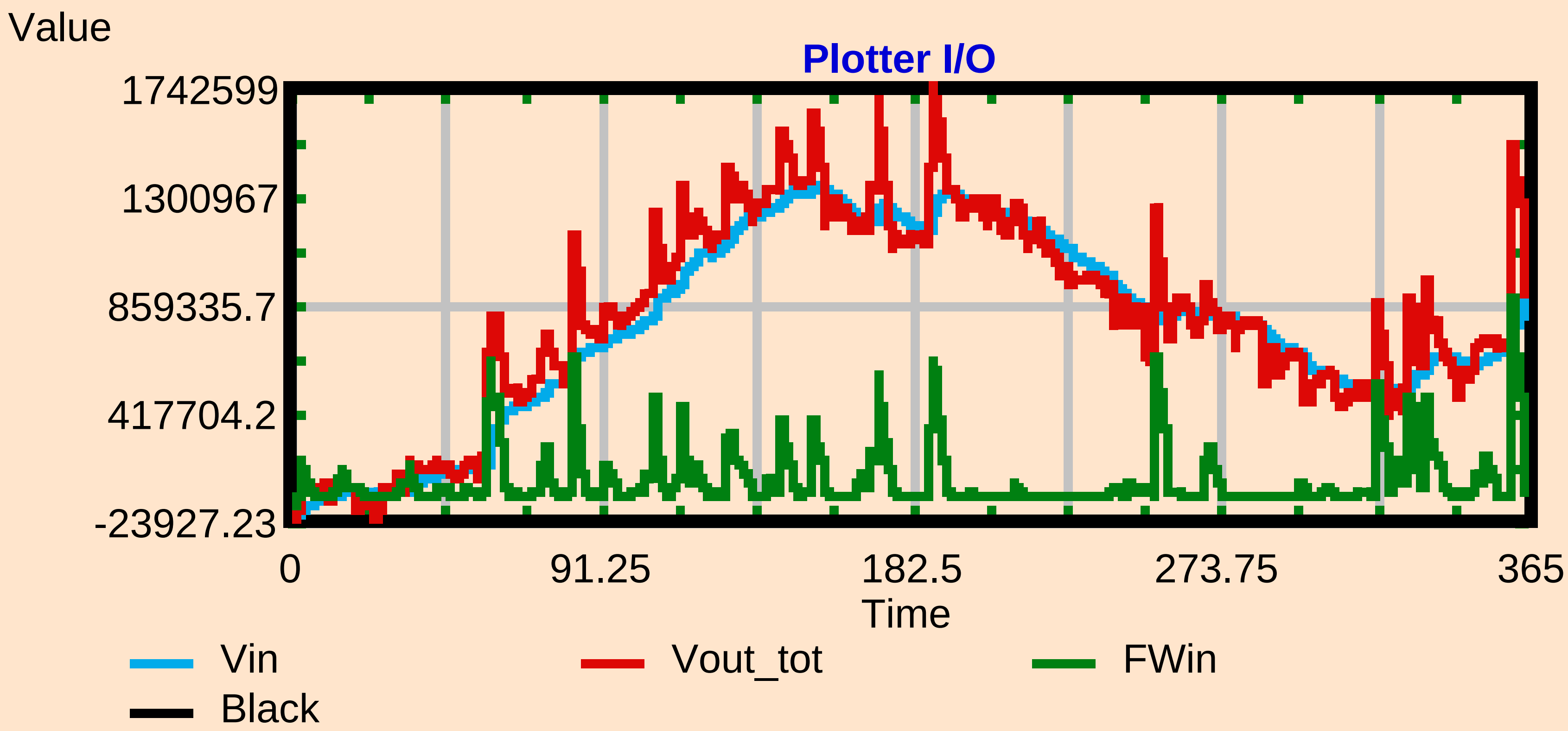
The freshwater balance represents the sum of the rain on Varna Bay surface, the land runoff, and the evaporation from the surface. The evaporation is calculated using the water-vapor pressure and temperature differences, and the surface wind. The runoff is estimated.

Precipitation on Varna Bay, Varna Lake Runoff, Land Surface Runoff Varna Bay, WWTPs discharge (m3/day)



CIRCULATION EXCHANGE:

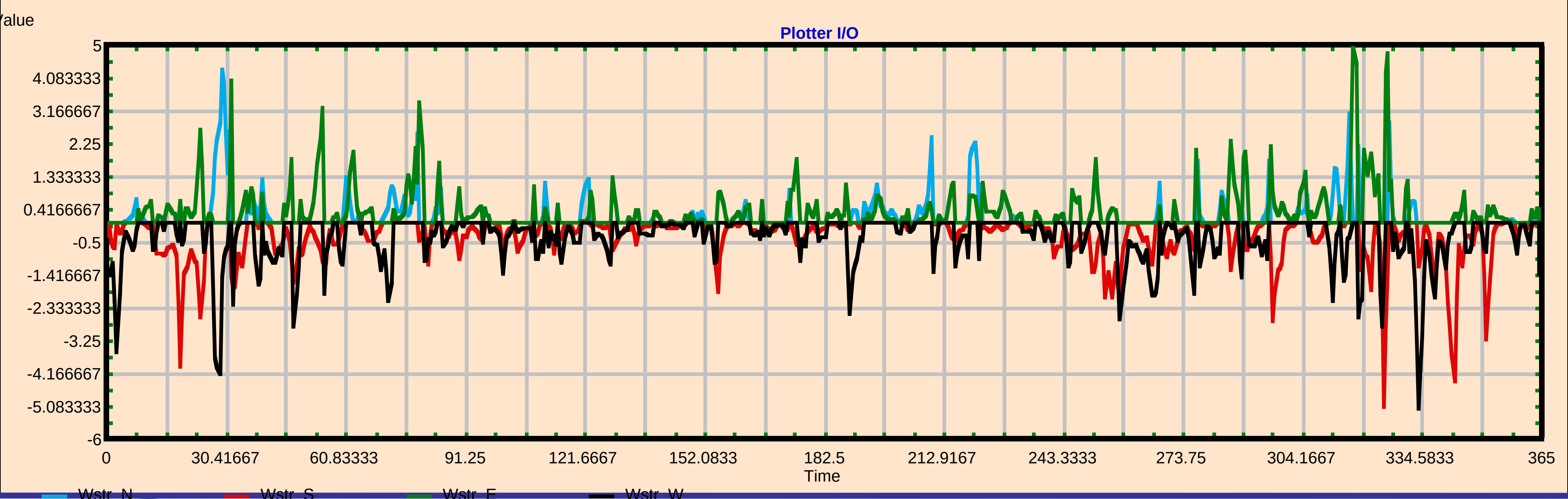
Based on the Fresh Water Exchange with Varna Lake, Fresh Water Exchange with open Black Sea, Fresh Water Exchange with Coastal Current



WIND STRESS VECTOR AND TRANSPORT:

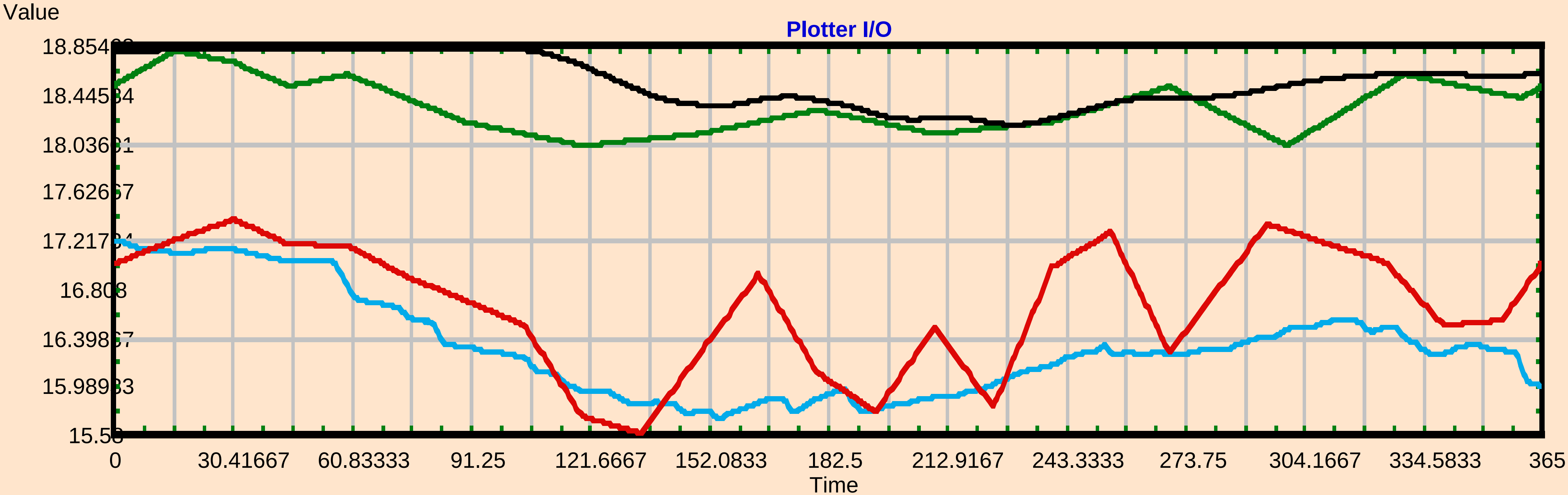
Here the air temperature is compared with a polynomial smoothed version of the same air temperature. Days with colder anomalies are attributed as coming from the north and warmer ones from the south. The humidity is only used to indicate the east-west orientation of the wind. The NE quadrant is cooler and wetter, the SE is warmer and wetter, the SW is warmer and drier, and the NW is cooler and drier.

Strongest winds from the northeast and northwest



SALT BUDGET:

Calculated the same manner as the one for the Varna lake submodel



Bottom salinity (promilles)-calculated values

Bottom salinity (promilles)-measured values

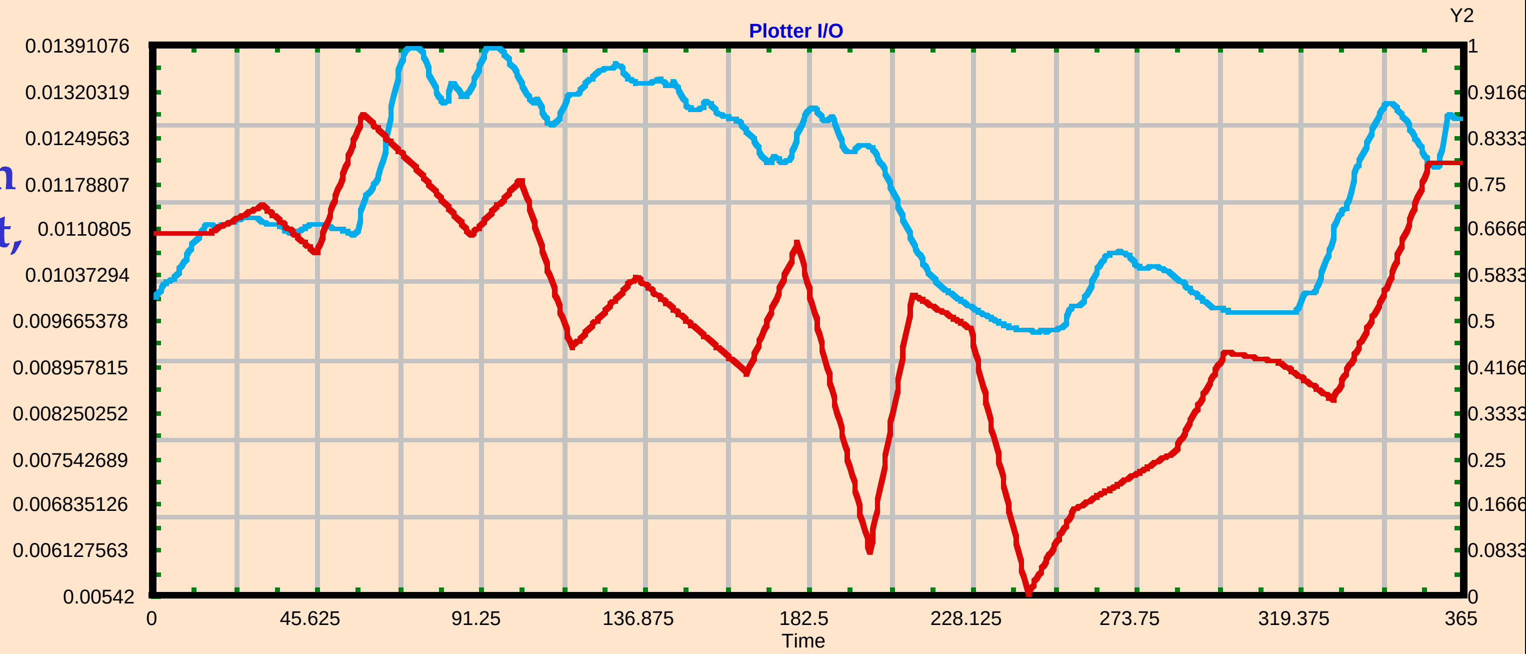
Surface salinity (promilles)-calculated values

Surface salinity (promilles)-measured values

OXYGEN BUDGET:

The oxygen is modeled because hypoxia is considered a key indicator of eutrophication. The available observations correspond to the modeled values, so that the oxygen budget remains within reasonable bounds.

Surface layer- the main sources are the photosynthetic production and the atmospheric input, OxyInfromBS, and adjectively entrained bottom water; and the sinks are those of respiration (phytoplankton) and of diffusive loss to the bottom layer.

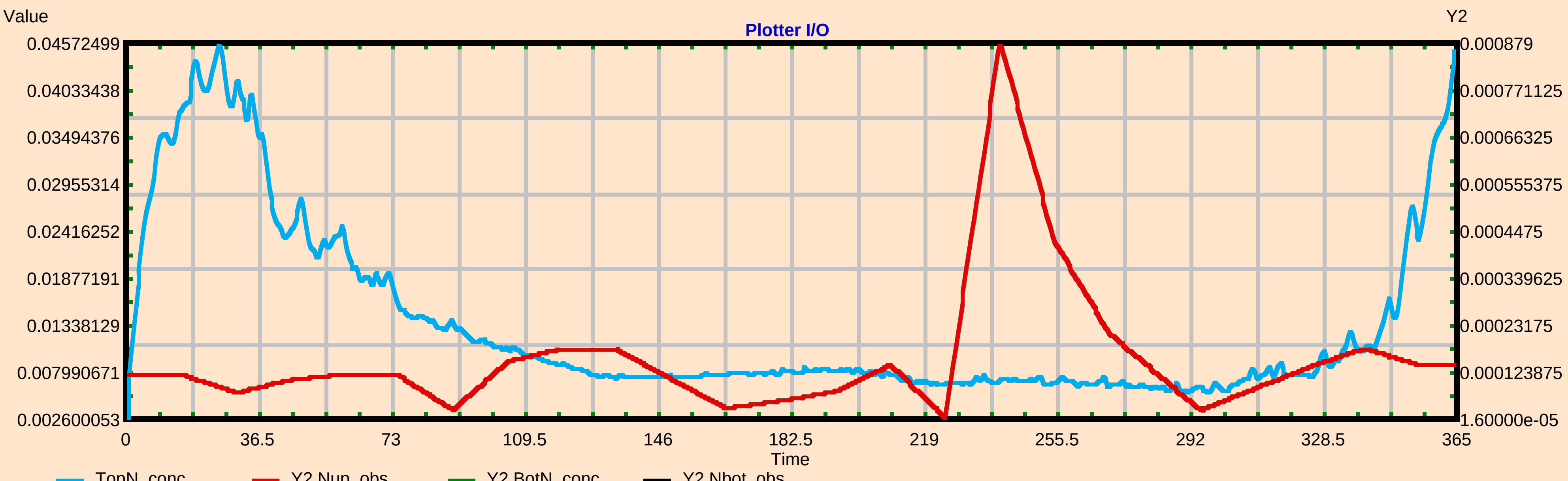


Dissolved Oxygen kg/m3

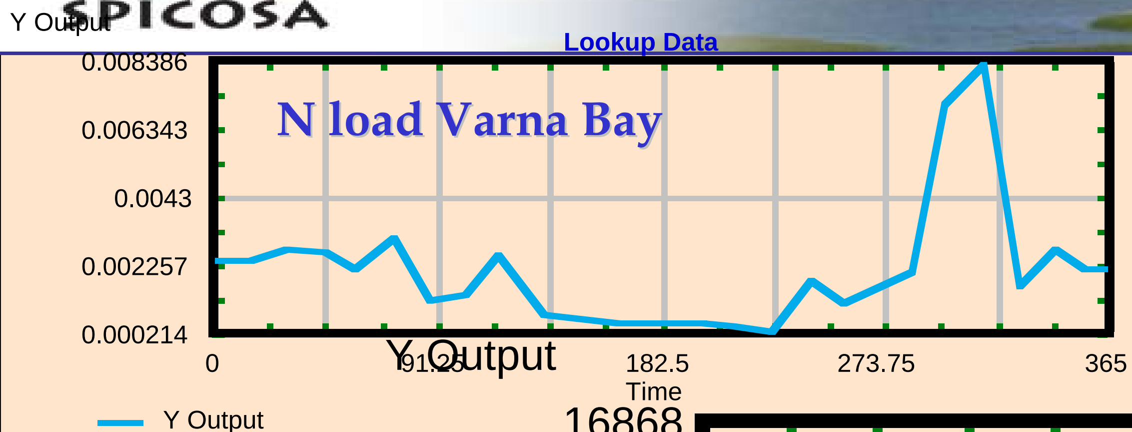
NITROGEN BUDGET:

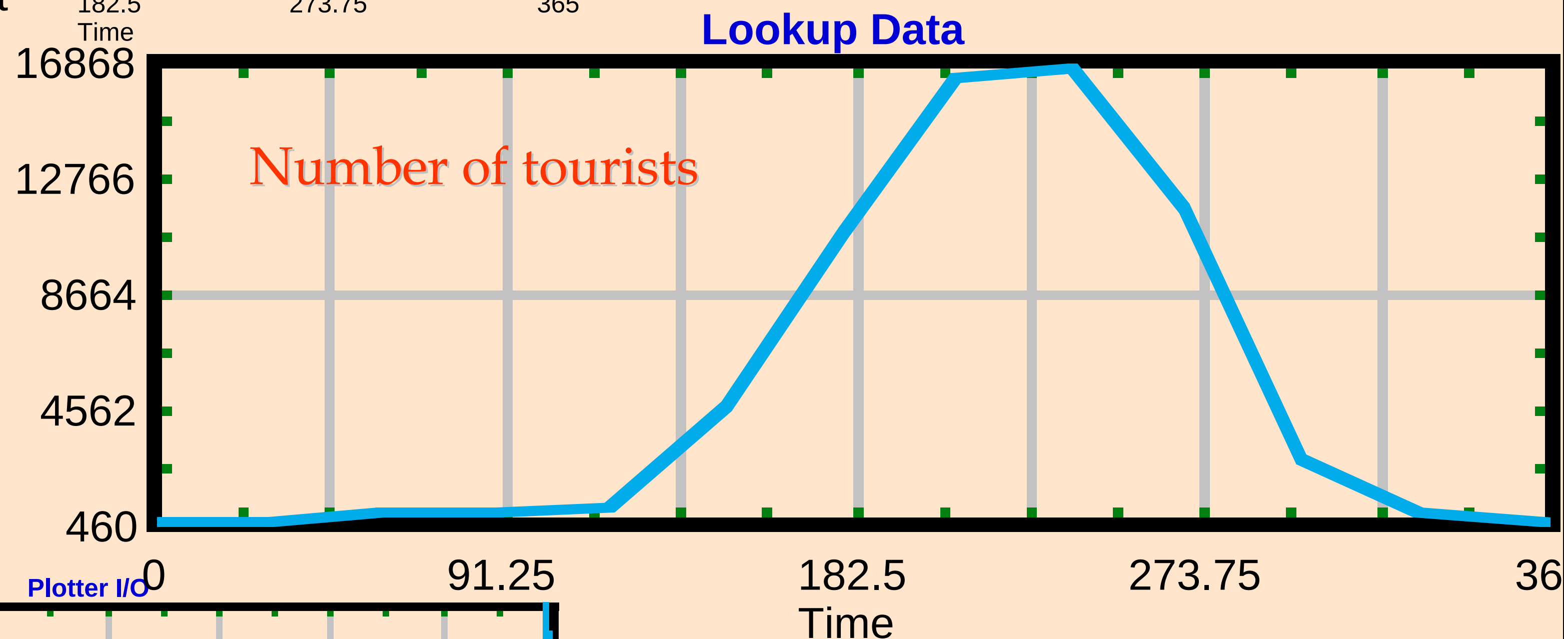
In constructing the budget, it is assumed that only the nitrogen stored in the top layer is available for photosynthesis and that not all of this nitrogen is immediately available for primary production. The budget has not yet been calibrated expecting changes in the phytoplankton component and TSS component.

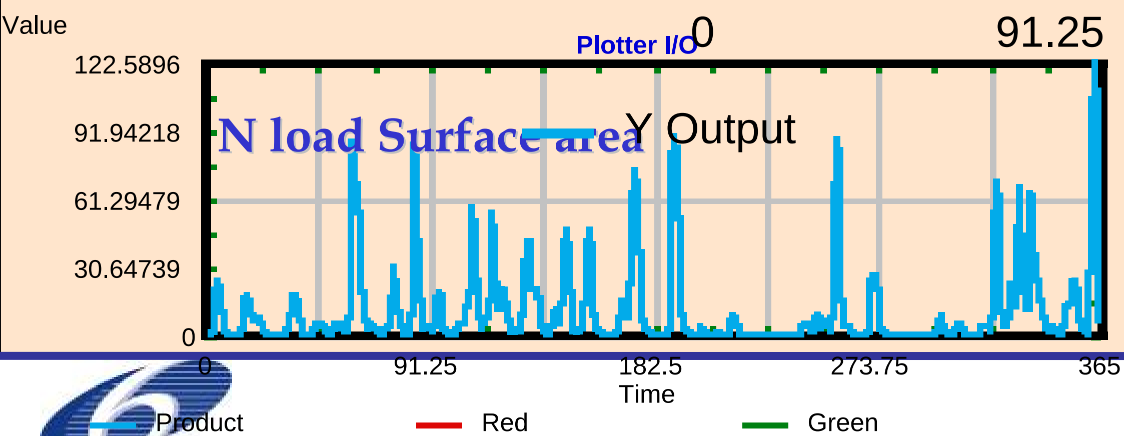
The surface layer inputs- from the atmospheric deposition, the land runoff, the WWTPs discharges, Varna lake discharge, and from the bottom layer, via entrainment and diffusion processes. **The surface layer loses-** phytoplankton uptake, advective outflow, and sinking to through the pycnocline.



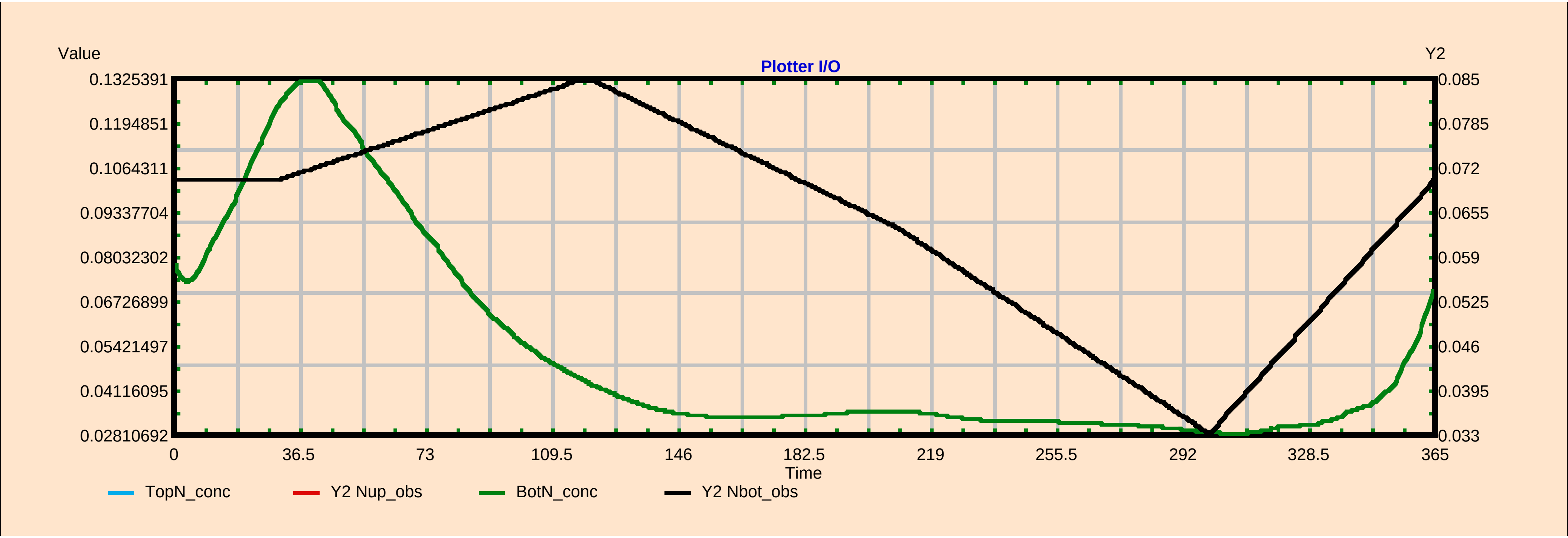
SPICOSA


Lookup Data
N load Varna Bay
Y Output
0.008386
0.006343
0.0043
0.002257
0.000214
0
91.25
182.5
273.75
365
Time
Y Output


Lookup Data
Number of tourists
16868
12766
8664
4562
460
0
91.25
182.5
273.75
36
Time
Y Output


Plotter I/O
N load Surface area
Value
122.5896
91.94218
61.29479
30.64739
0
0
91.25
182.5
273.75
365
Time
Product
Black
Red
Green

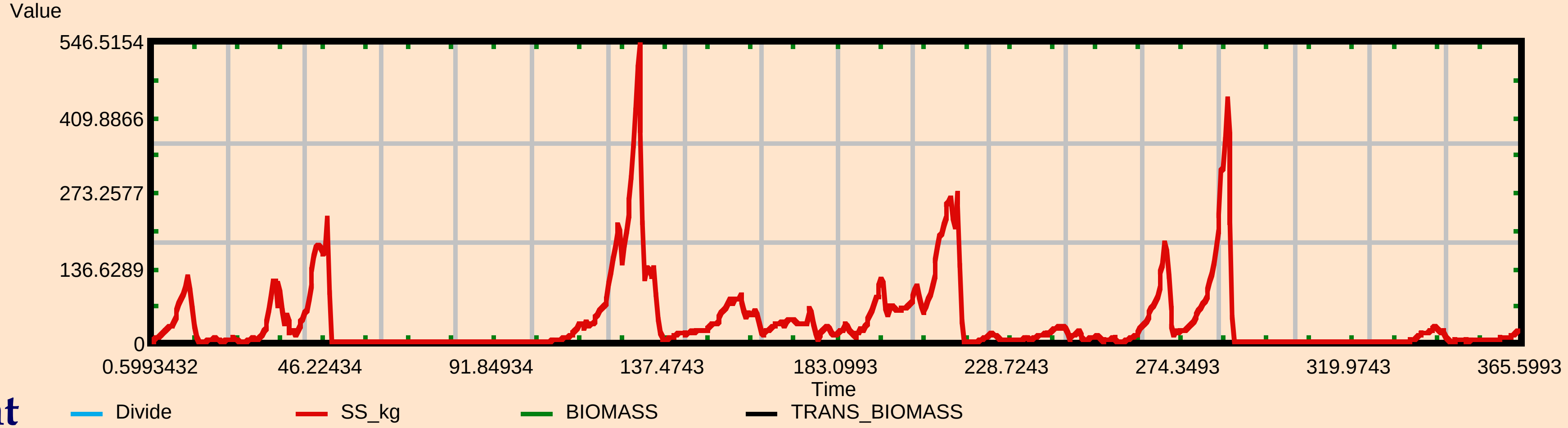
The bottom layer gains N from regeneration, advection, and it loses N to the upper layer through the same entrainment and diffusion processes and through burial.



Nitrogen processes are formulated as follows:

- **Entrainment,** as an upwelled flux of bottom water;
- **Diffusion,** as proportional to the vertical N-gradient using the same coefficient as Salinity;
- **Uptake,** as the amount available up to the saturation value (associated with each of the two phytoplankton classes);
- **Sinking,** calculated as a percent of the Biomass_total in the surface layer and the ratio of N: C biomass;
- **Regeneration,** as approximately equal to literature values ;
- **Advection**, as the flux of inflow or outflow times the N concentration;
- **Sediment burial**, as approximately equal to literature values for similar deposition rates;
- **Denitrification,** as approximately equal to literature values .

SUSPENDED SEDIMENT



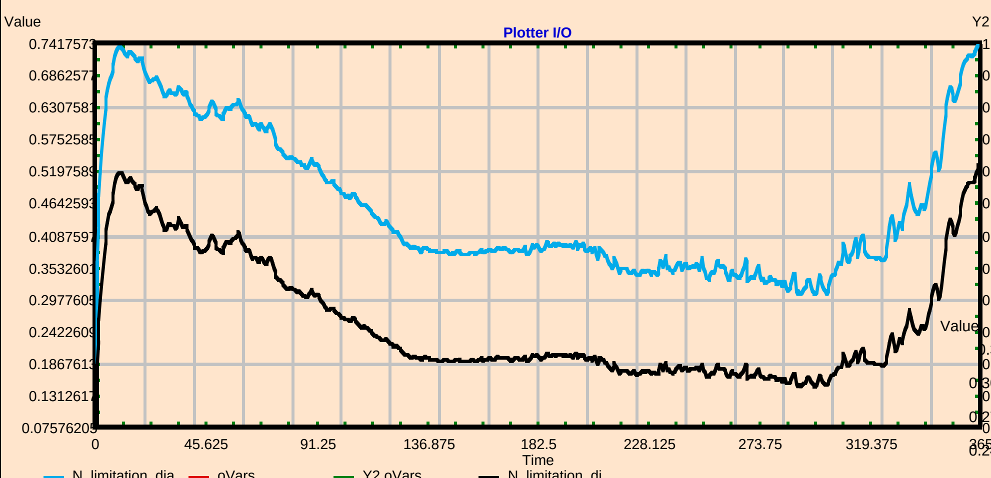
Inputs:

- Rain
- Wave height
- Wave period
- Concentration of suspended solids in storm water
- Concentration of suspended solids in river
- Area and depth (volume) of water being studied
- River flow
- Depth of water column
- Height above seabed used to determine re-suspension of sediment due to waves
- Diameter of seabed sediment
- Salinity of coastal water

The inputs are used to determine suspended solids caused by combined sewer overflow (CSO) events and wave re-suspension of bottom sediment. It is currently assumed that suspension of solids does not last longer than the end of each day.

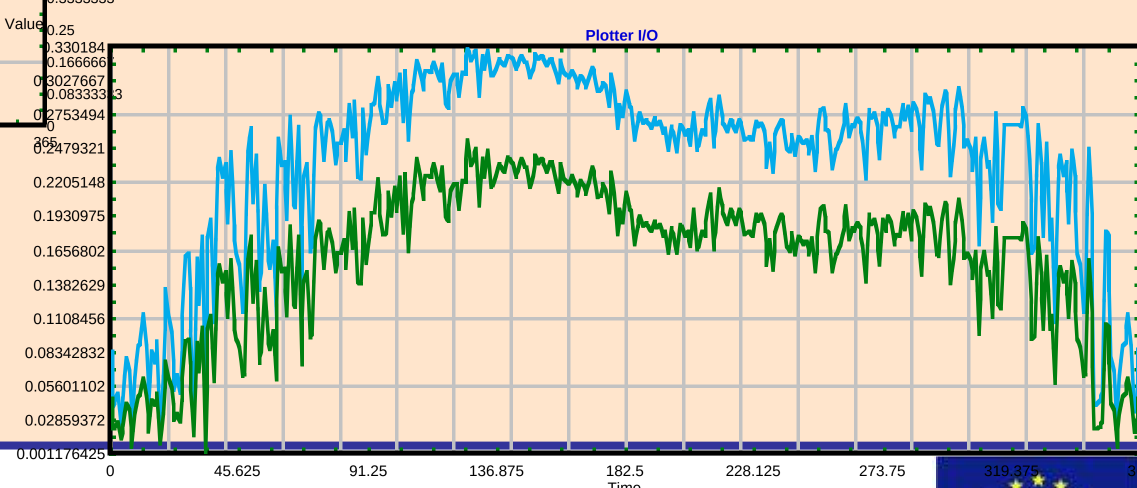
PHYTOPLANKTON

The current formulation includes two phytoplankton groups in order to simulate their seasonal variations and the direct effect of phytoplankton blooms over the water transparency. Each has a different growth curve defined by different optimum light conditions and a separate nitrogen-growth curve. Light values are from observed irradiance-light absorption is different for the two groups



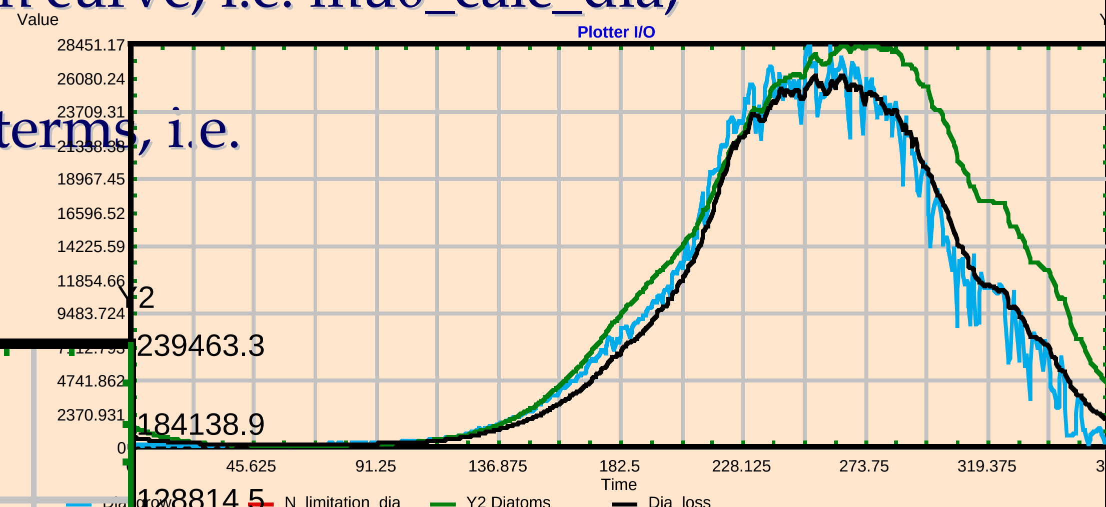
NITROGEN LIMITATION

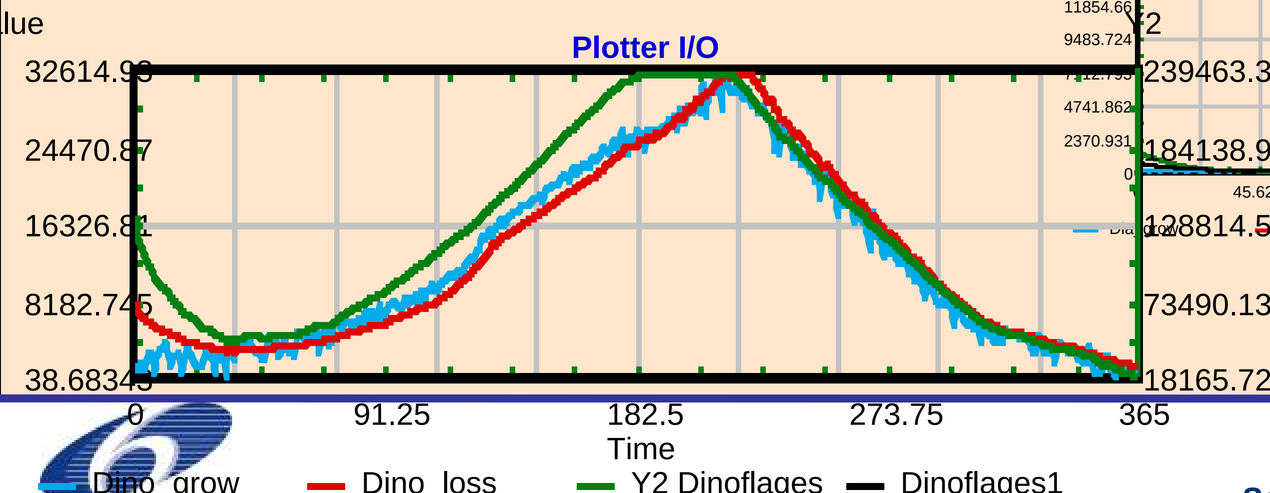
LIGHT LIMITATION



Some formulation aspects:

- two taxonomic groups are considered: diatoms and dinoflagellates;
- each of the groups has a separate nitrogen-growth curve F(N) (Michaelis-Menton) and function of light intensity F(I);
- all have the same coefficients for respiration=Kr but different for mortality=Km and grazing=Kg;;
- each is exposed to a different grazing fraction of total grazers;
- all have different exponential growth curve, i.e. mu0_calc_dia, mu0_calc_dino;
- all have population dependent loss terms, i.e. PPloss=(PP)*(Kr+ Km)+ZP*PP*Kg





Phytoplankton growth (mu) is function of light F(I), temperature F(T) and dissolved nitrogen F(N):

mu=mu_max*f(I)*f(N)*f(T) where mu_max is the maximum daily growth rate (d-1) *(A. Chapelle et al. : Ecological Modelling 127 (2000))*

F(I)=1/z I/Iopt*e^(1-I/Iopt)*dz*dt

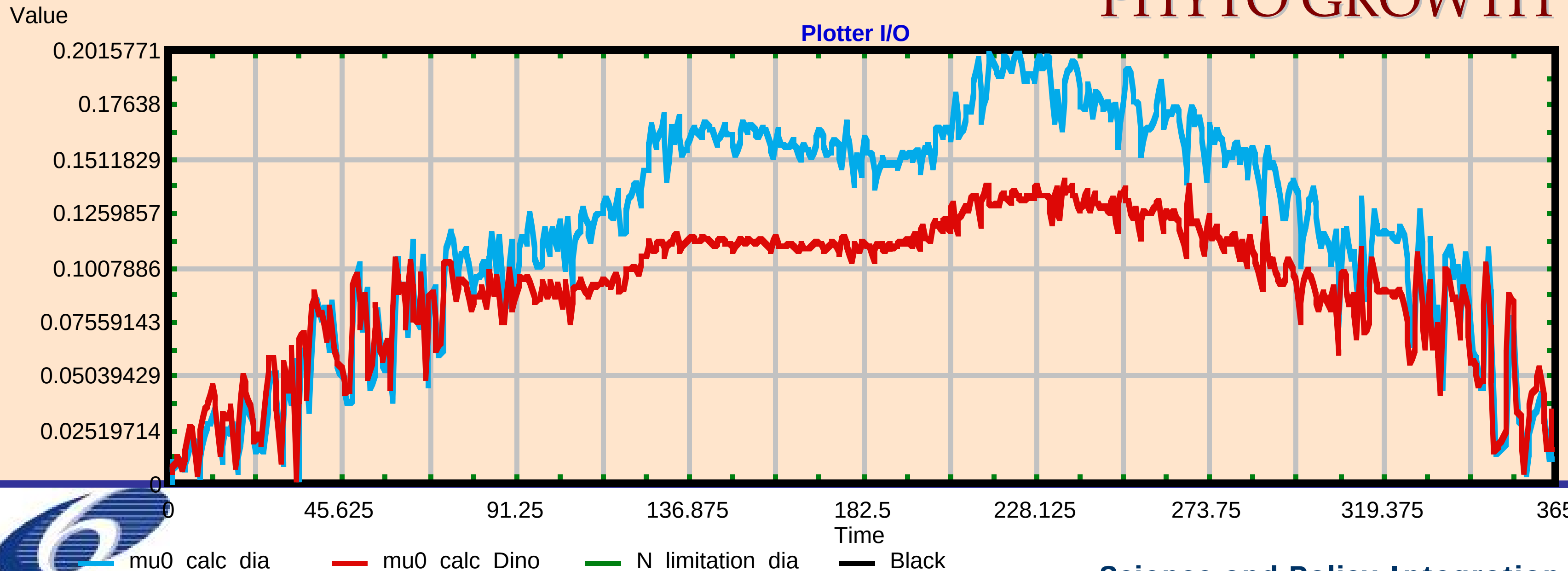
For I<Iopt and F(I)=1 for I>Iopt

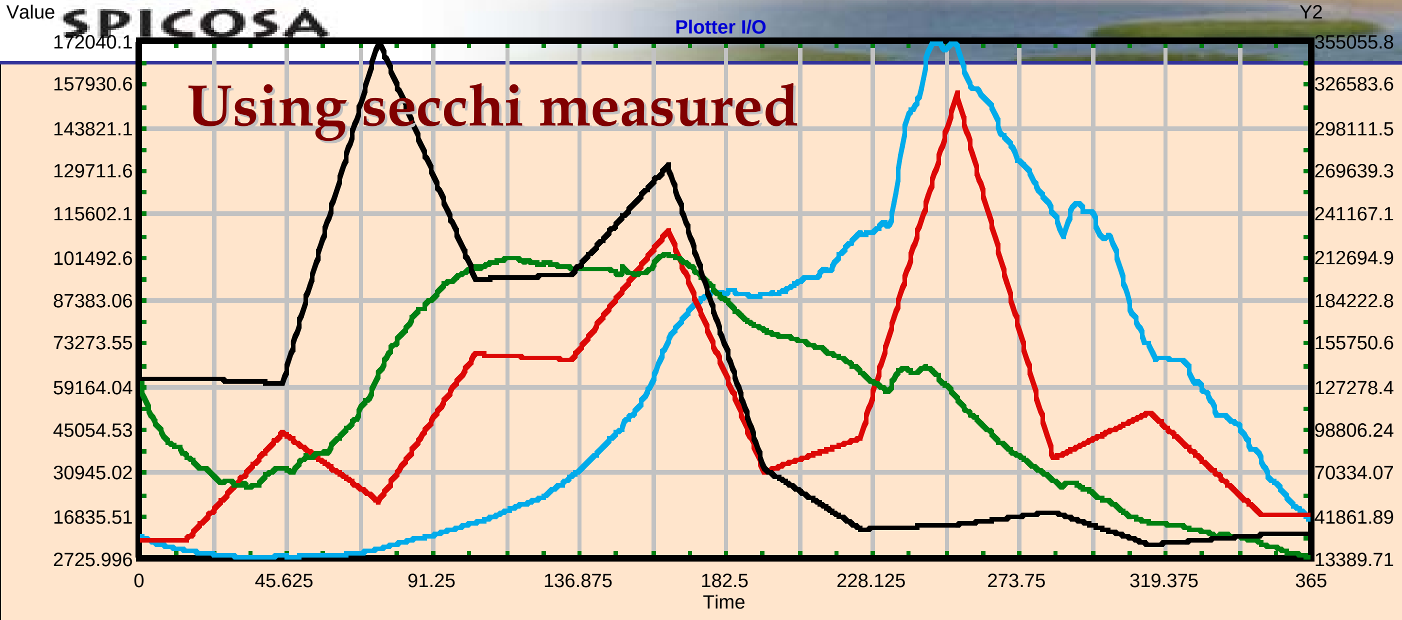
I=Isur*e^(KD*z)

KD-extinction coefficient dynamicaly calculated KD=1.4/secchi_depth

F(T)=e^kT*temp_water

PHYTO GROWTH (mu)

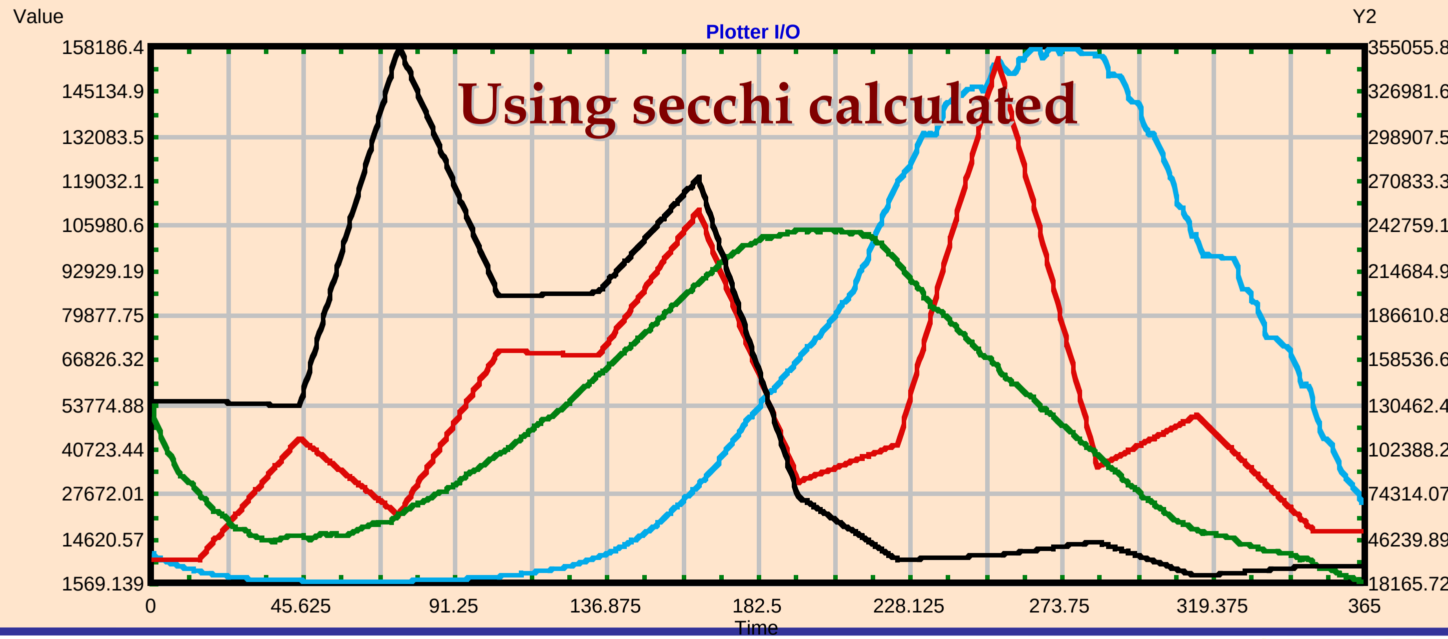




Phytoplankton biomass Kg Carbon C

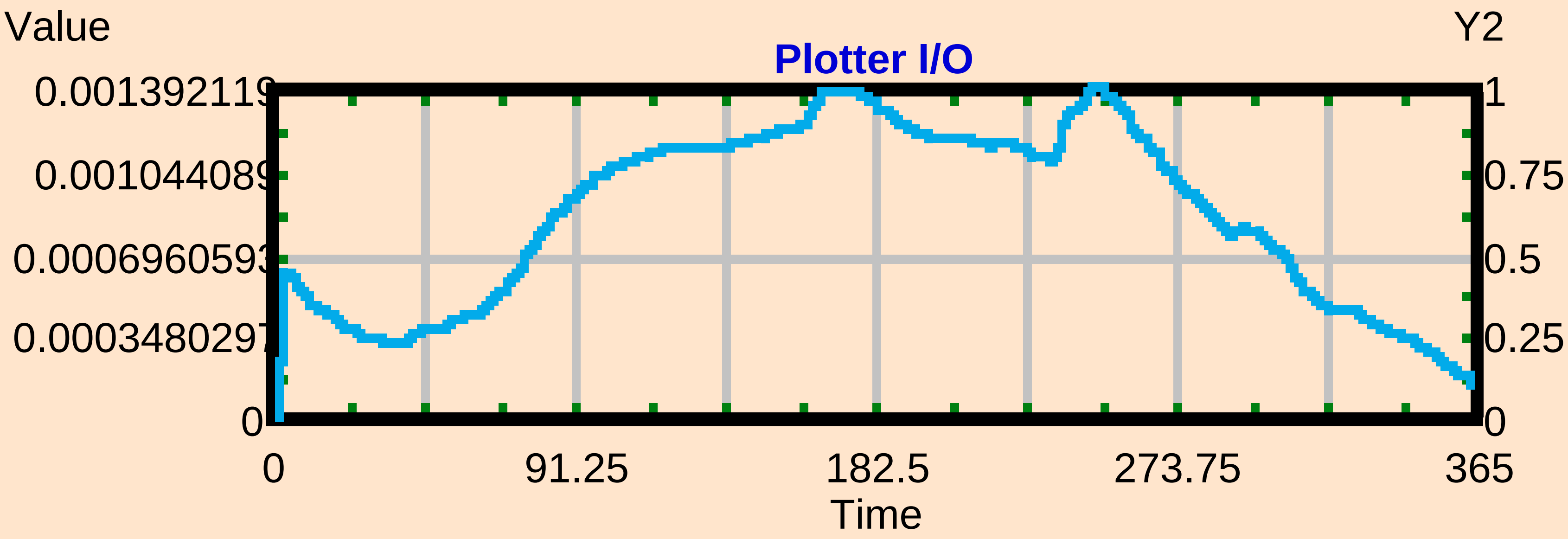
PP_Dia= 0.226667359580709983 = 226 gr C m-1 y-1

PP_Dino = 0.3870521098463415 8 = 387 gr C m-1 y-1



ZOOPLANKTON

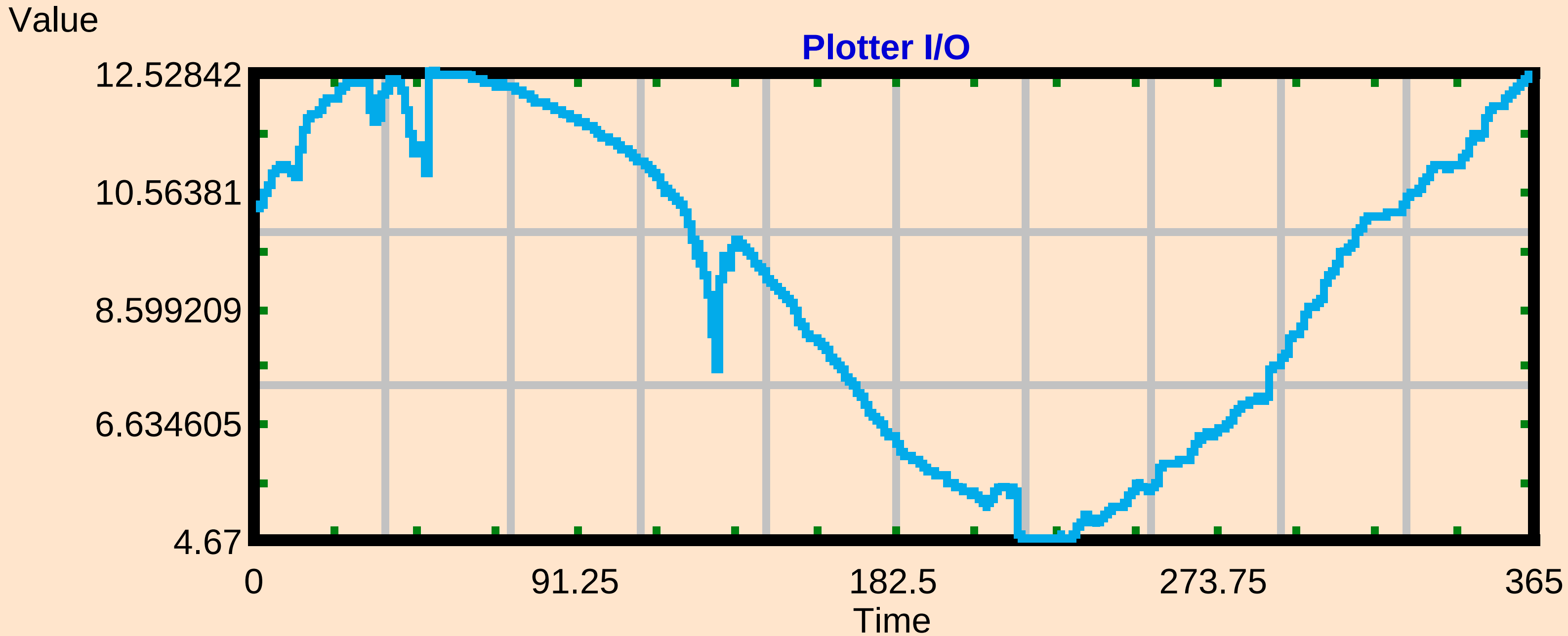
In the current model the grazers are considered as a fixed population. Grazing factors for the two groups of phytoplankton- after Temel Oguz et.al. *(Modeling the response of top-down control exerted by gelatinous carnivores on the Black Sea pelagic food web, 2001)*



SECCHI DEPTH

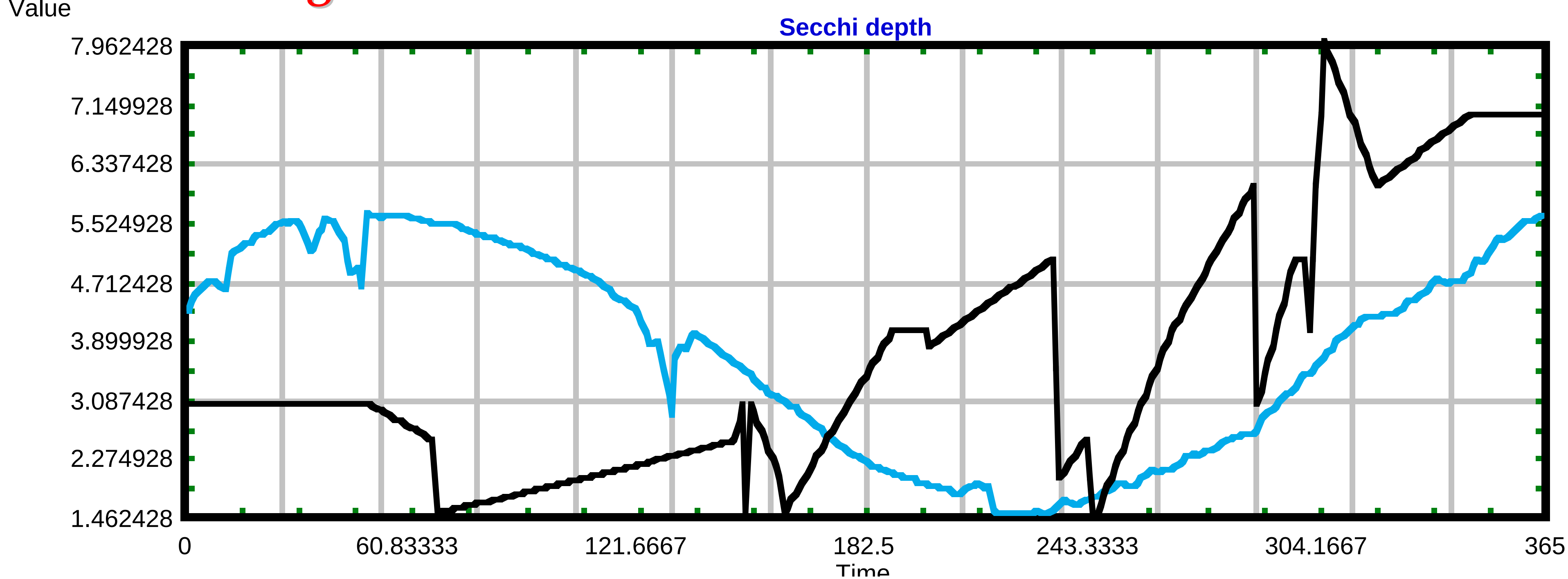
Relationship between phytoplankton biomass and TSS has been established using General Regression Model (Factorial regression). The established relation is used at each time step to calculate the secchi depth, and the resulting value is used at the next time step for calculating the euphotic layer depth (depth at which the incoming light is being integrated).

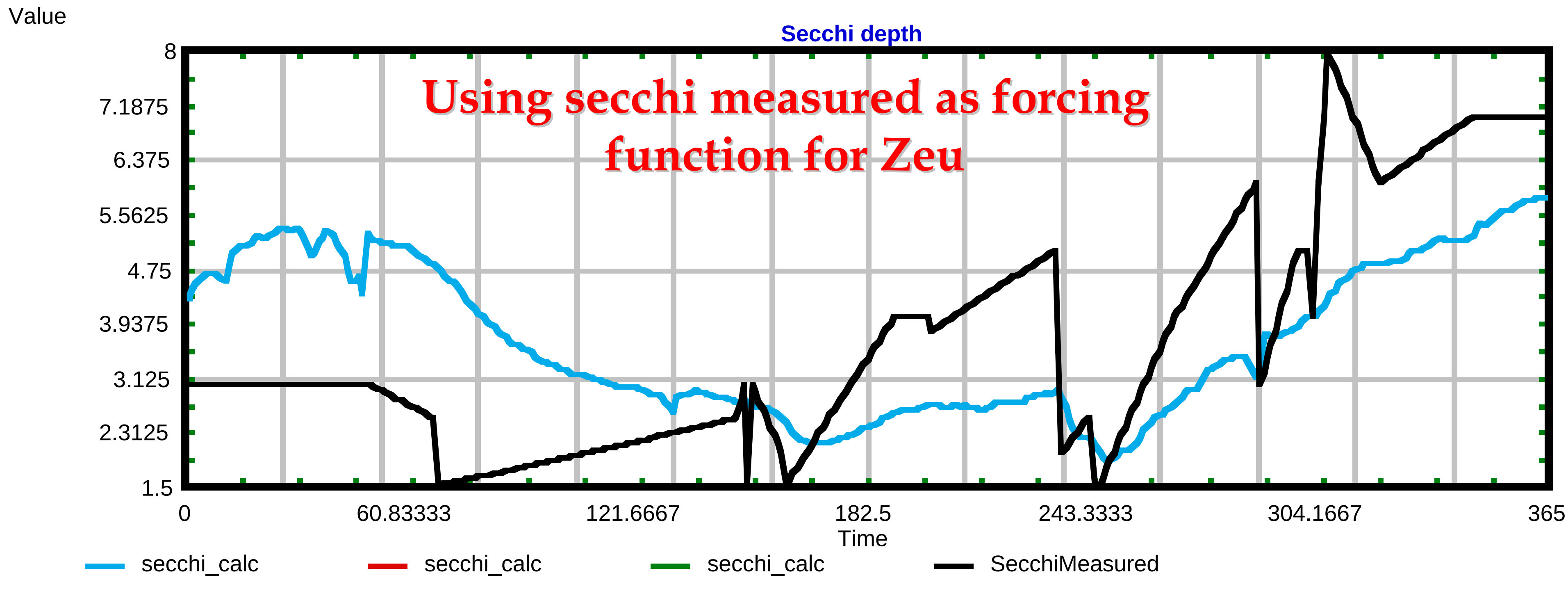
Zeu=1.4/Secchi_calc



euphotic layer depth

Using secchi calculated





Requirements for discharges from urban waste water treatment plants to sensitive areas which are subject to eutrophication as identified in EU DIRECTIVE 98/15/EO from 27.02.1998

N total -10 mg/l or 70-80 % reduction
P total - 1 mg/l or 70-80 % reduction
(> 100 000 inhabitants)

Parameters by the technical manual for the reconstruction of WWTP Varna:

Inputs WWTP Varna:

N tot – 40 mg/l

→ 10 %

Mechanical treatment:

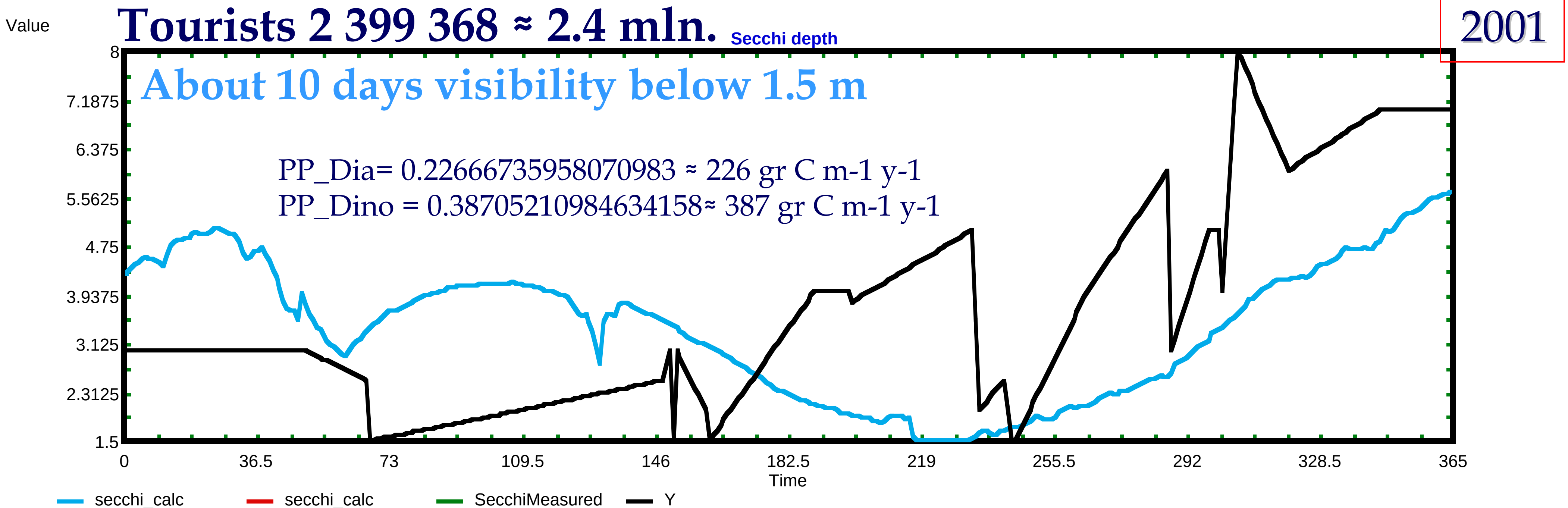
N tot – 36 mg/l

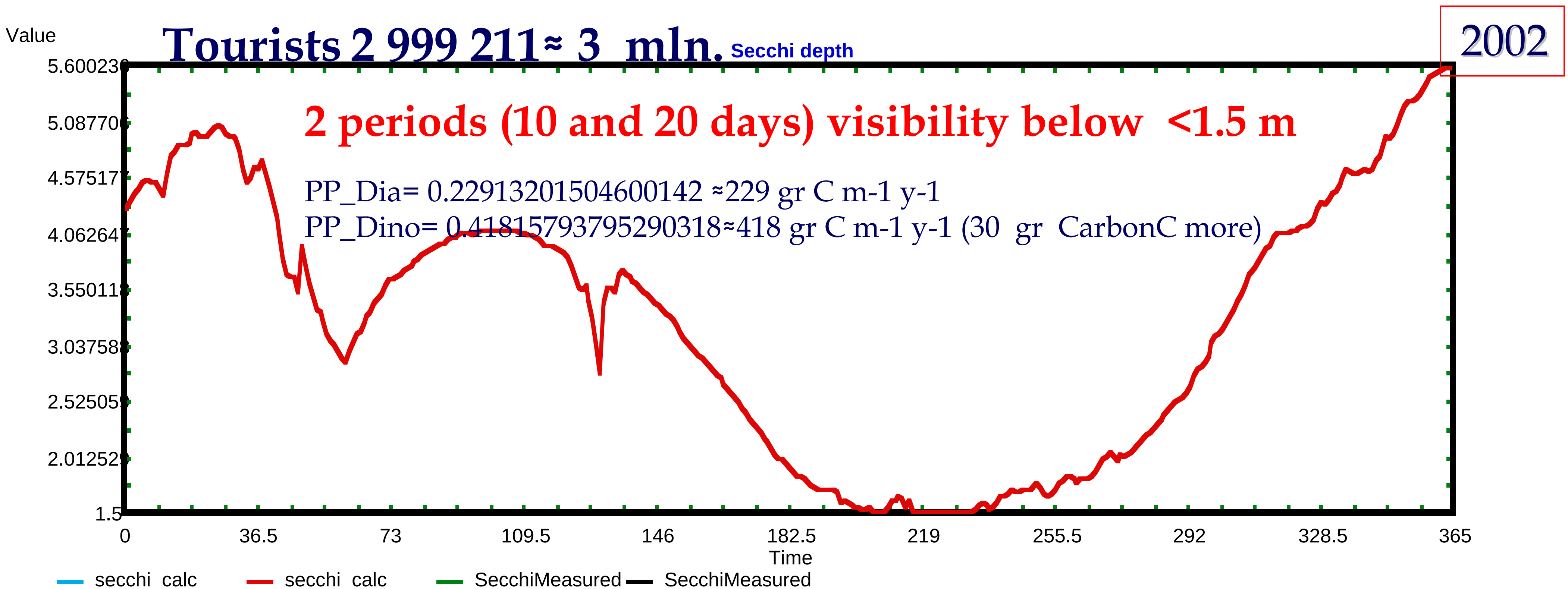
→ 65 %

Bioreactors:

N tot – 10 mg/l

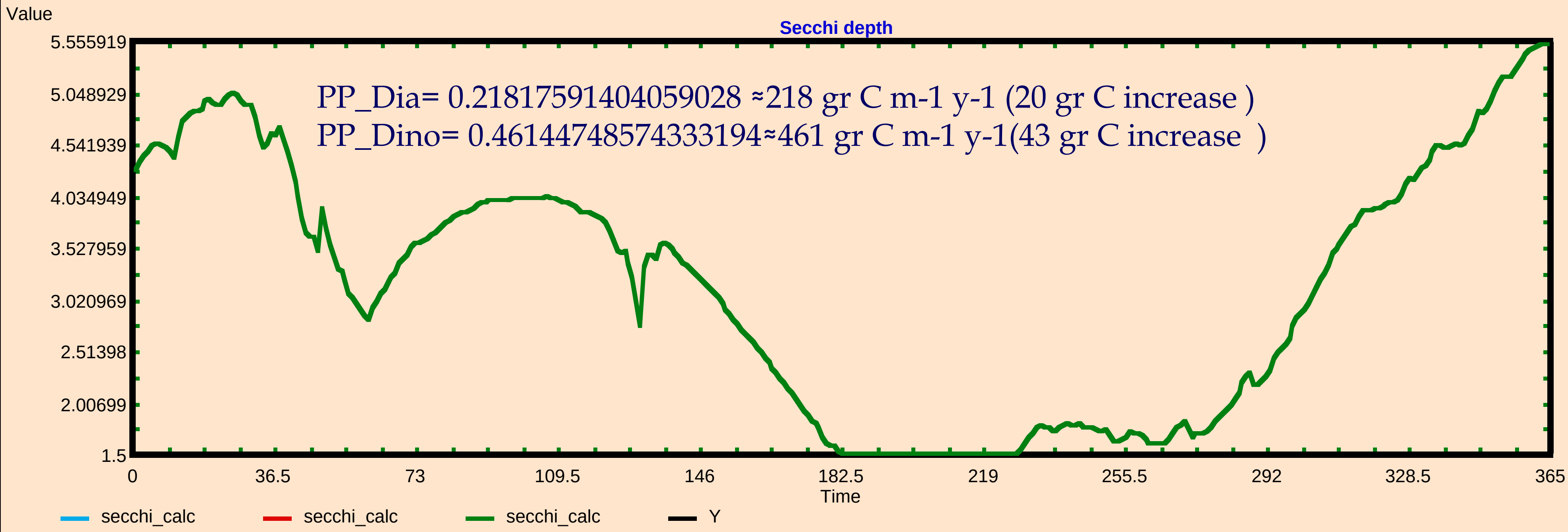
75 %


Tourists 2 399 368 ≈ 2.4 mln.
Secchi depth
2001
About 10 days visibility below 1.5 m
PP_Dia= 0.22666735958070983 ≈ 226 gr C m-1 y-1
PP_Dino = 0.38705210984634158≈ 387 gr C m-1 y-1
Value
8
7.1875
6.375
5.5625
4.75
3.9375
3.125
2.3125
1.5
0
36.5
73
109.5
146
182.5
219
255.5
292
328.5
365
Time
secchi_calc
secchi_calc
SecchiMeasured
Y


Tourists 2 999 211≈ 3 mln.
Secchi depth
2002
2 periods (10 and 20 days) visibility below <1.5 m
PP_Dia= 0.22913201504600142 ≈229 gr C m-1 y-1
PP_Dino= 0.41815793795290318≈418 gr C m-1 y-1 (30 gr CarbonC more)
Value
5.600236
5.087706
4.575177
4.062647
3.550118
3.037588
2.525059
2.012529
1.5
0
36.5
73
109.5
146
182.5
219
255.5
292
328.5
365
Time
secchi_calc
secchi_calc
SecchiMeasured
SecchiMeasured

Tourist 3 799 000≈ 4 mln.

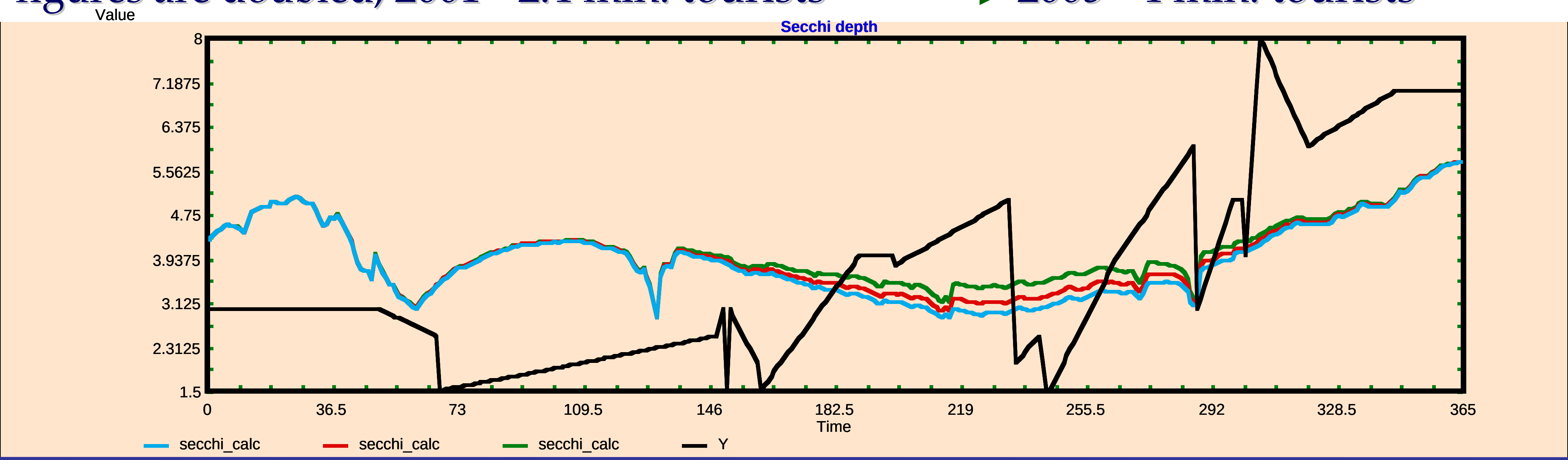
50 days visibility below <1.5 M



SCENARIOS

Upgrade of the existing WWTP along the resorts, performed in the same manner as currently undergoing for WWTP Varna, also included in the Municipality Action Plan as a part of the National Plan for the Environment for 2007-2013, will lead to improvement of the water quality- reducing the phytoplankton blooms and related to it the Secchi depth variability.

If full denitrification of the nutrients discharged in Varna Bay system by WWTPs along the resorts is being performed (reduction 75% of incoming concentrations), decrease of water transparency will be in order of magnitude less even if tourists figures are doubled; 2001 - 2.4 mln. tourists → 2005 - 4 mln. tourists



The result of such adequate treatment will lead to zero days with water transparency less than 1.5 m.

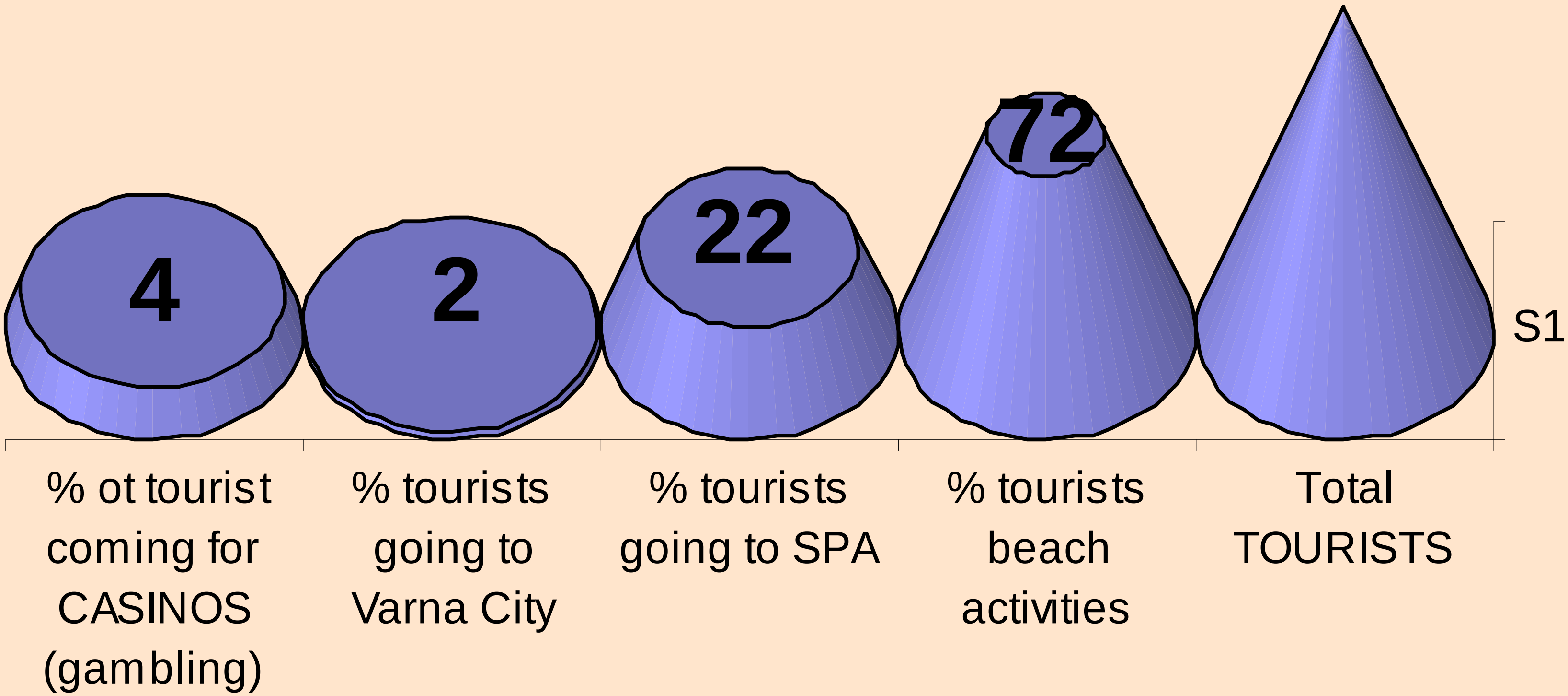
This, along with the fact for which 65 % randomly selected people are reported to be sensitive and will not to go swimming at the beach if the water transparency is below 1.5 m, gives the necessary feedback to the ecological component (e.g. Social component: Public perception/demand (willingness to pay for WQ improvement/ good ecological status maintenance- questionnaire EC project Threshold)

CONCLUSION:

✓ The model adequately demonstrates the reaction of the system on changes (increase and decrease) of nutrient loads

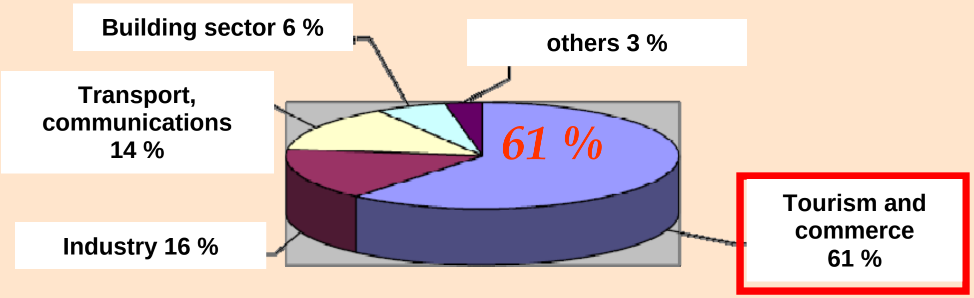
✓ The relationships between reduction of nutrient loads in Varna Bay and achievement of desired values of the parameter Water Transparency have nonlinear pattern

✓ Despite this fact, one can conclude that in the case of general reduction of nutrient loads the model sufficiently represents the improvement of water optical characteristics (water clarity)



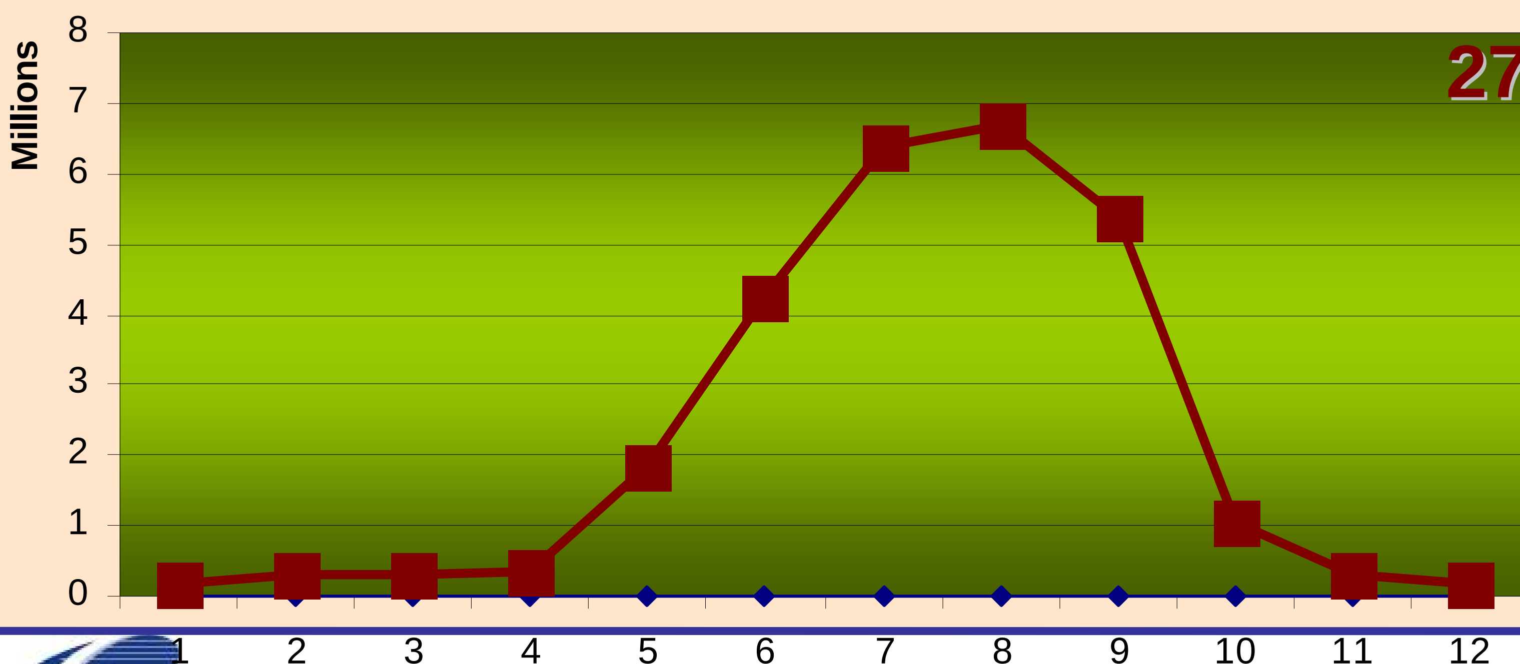
Distribution of different tourist groups (%)

Net income by sectors -Varna district

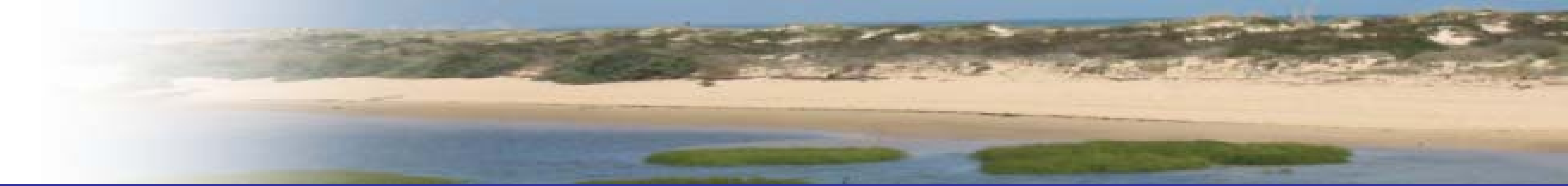


30% will not go to beaches if <2 m
65% will not go to beaches if <1.5 m
90% will not go to beaches if <1 m

72 % are using Varna beach for BATHING

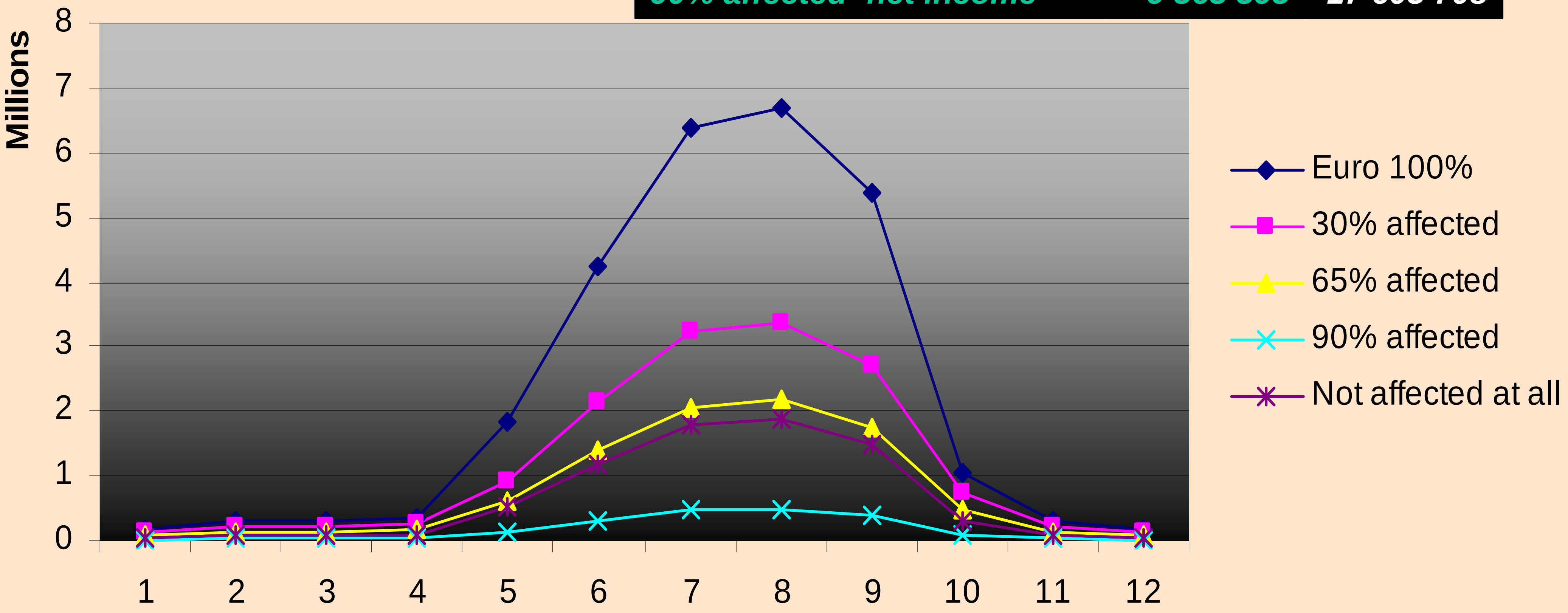


27 Mln. Euro/year
(27 169 302)



27 Mln. Euro/year (27 169 302)

	Income EU	Loss EU
30% affected -net income	*21 300 733*	*5 868 569*
65% affected -net income	*16 410 259*	*10 759 044*
90% affected -net income	*9 563 595*	*17 605 708*



SPICOSA

We would like to cordially acknowledge the contribution of Prof. Tom Hopkins

VARNA BAY

Data concerns

- Still having troubles finding good met data
- inadequate/poor/old socio-economic data
-Unable to verify the extent of urban runoff into coastal water

Formulation concerns not sure how
-to express the coastal current contribution (open sea/Varna Bay)

Extend Concerns

- need help on setting up the social analysis
- assistance in the methods for assessment of "aesthetic, rehabilitation value"
- there are currently no direct feedbacks between the social and economic components and the natural component