Workshop on Baltic Sea Ecosystem in Changing Climate
Oct. 16, 2009, Norrkøping, Sweden

Seasonal Variability in the Baltic Sea Ecosystem

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Outlines

- Model features
- Model configuration
- Validation
- Seasonal variability

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Physical Model

CMOD - the Circulation MODel

originally developed by Bundesamt fuer, BSH

completely re-written, optimised, parallelised and further developed at DMI, by Per Berg, Jacob Weismann Poulsen and others

- primitive hydro- and thermodynamic equations
- 2-order turbulence enclosure
- free surface, drying/flooding being implemented
- 2-way-nested
- 1D dynamic allocatable arrays
- openmp and/or MPI parallelization

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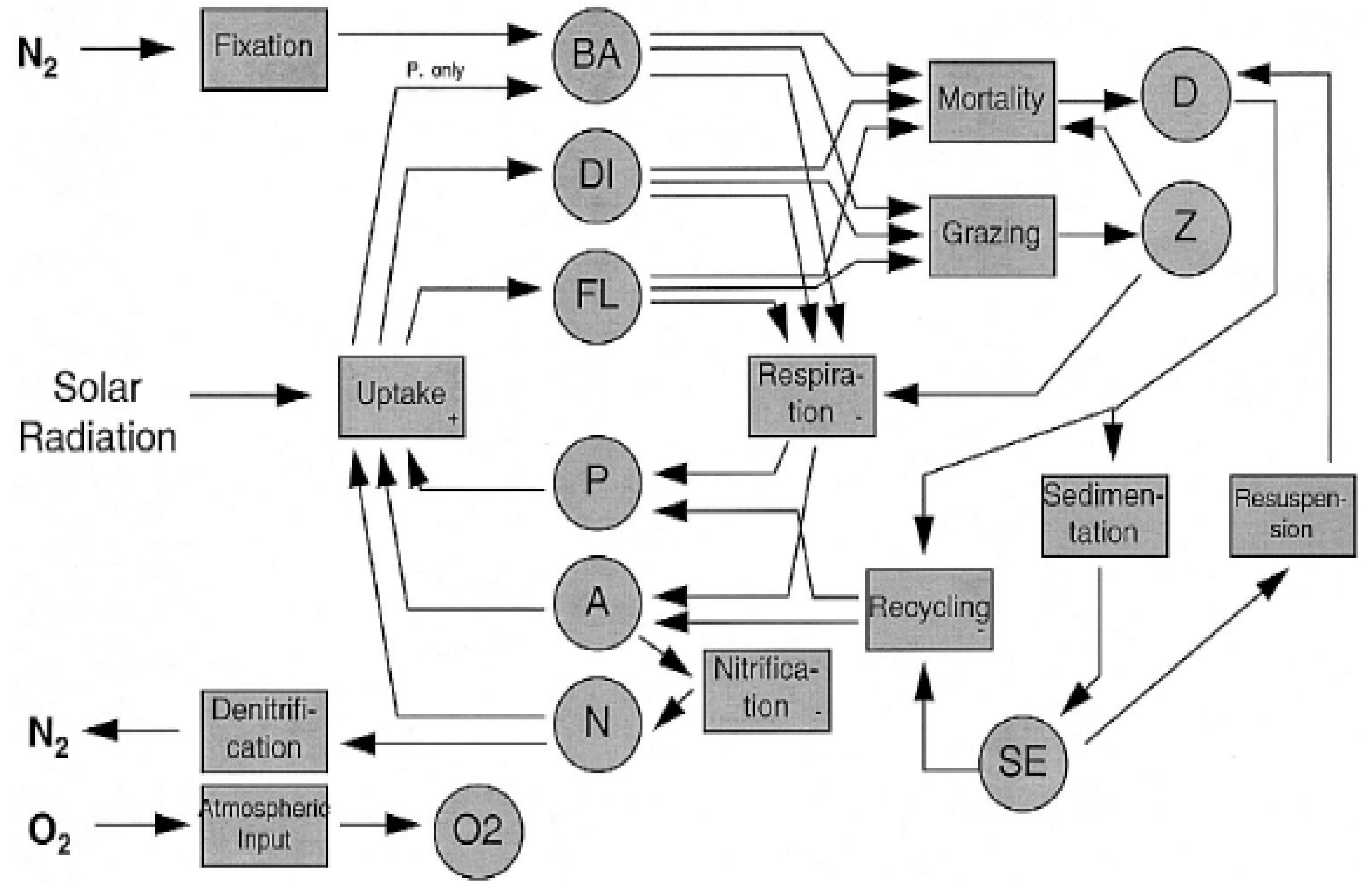
ERGOM Model by T. Neumann



T. Neumann / Journal of Marine Systems 25 (2000) 405–419

$$\dot{A} = -\sum_{n=1}^{2} RA_n P_n + REC \cdot D + \frac{RECS}{H_{BOT}} SED + LPN \sum_{n=1}^{3} P_n + LZN \cdot Z^2 - NF \cdot A + \frac{AFLX}{H} \qquad (B1)$$

$$\dot{N} = -\sum_{n=1}^{2} RN_n P_n + NF \cdot A - 5.3\left(REC \cdot D + \frac{RECS}{H_{BOT}} SED\right) \times (1 - OSWTCH) NSWTCH + \frac{NFLX}{H} \qquad (B2)$$

$$\dot{PO} = RFR\left[REC \cdot D + LPN \sum_{n=1}^{3} P_n + LZN \cdot Z^2 - \sum_{n=1}^{3} R_n P_n\right] + \frac{POFLX}{H} \qquad (B3)$$

$$\dot{P}_n = R_n P_n - LP \cdot P_n - G_n Z; \qquad \{n = 1,2,3\} \qquad (B4)$$

$$\dot{Z} = G \cdot Z - LZ \cdot Z^2 \qquad (B5)$$

$$\dot{D} = LPD \sum_{n=1}^{n} P_n + LZD \cdot Z^2 - (REC + SEDR) D + RES \cdot SED \qquad (B6)$$

$$\dot{O2} = \frac{Nnorm}{Onorm}\left[\frac{6.625 \cdot A + 8.125 \cdot N}{A + N} \sum_{n=1}^{3} R_n P_n - 1.5 \cdot NF \cdot A - 6.625\left(LPN \sum_{n=1}^{3} P_n + LZN \cdot Z\right) - 6.625\left(REC \cdot D + \frac{RECS}{H_{BOT}} SED\right)(NSWTCH \cdot OSWTCH + (1 - NSWTCH))\right] - 1.5 \cdot \frac{RECSN}{H_{BOT}} \times SED \cdot OSWTCH + \frac{OFLX}{H} \qquad (B7)$$

$$\dot{SED} = SEDR \cdot D - (RES + RECS) \cdot SED - RECSN \cdot SED \qquad (B8)$$

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$$\mathrm{RA}_n = \frac{\mathrm{A}}{\mathrm{A}+\mathrm{N}} R_n \qquad \text{(B9)}$$

$$\mathrm{RN}_n = \frac{\mathrm{N}}{\mathrm{A}+\mathrm{N}} R_n; \qquad \{n = 1,2,3\} \qquad \text{(B10)}$$

$$R_1 = R\mathrm{D0} \cdot \min(\mathrm{NLIM}_1, \mathrm{PLIM}_1, \mathrm{PPI});$$
$$\text{diatoms} \qquad \text{(B11)}$$

Diatom growth independent of temperature

$$R_2 = R\mathrm{F0} \cdot \mathrm{TLIM}_2 \cdot \min(\mathrm{NLIM}_2, \mathrm{PLIM}_2, \mathrm{PPI});$$
$$\text{flagellates} \qquad \text{(B12)}$$

$$R_3 = R\mathrm{B0} \cdot \mathrm{TLIM}_3 \cdot \min(\mathrm{PLIM}_3, \mathrm{PPI});$$
$$\text{blue-greens} \qquad \text{(B13)}$$

$$\mathrm{NLIM}_n = \frac{(\mathrm{A}+\mathrm{N})^2}{\alpha_n + (\mathrm{A}+\mathrm{N})^2} \qquad \text{(B14)}$$

$$\mathrm{PLIM}_n = \frac{\mathrm{PO}^2}{\mathrm{RFR} \cdot \alpha_n + \mathrm{PO}^2} \qquad \text{(B15)}$$

$$\mathrm{TLIM}_2 = 1 + \frac{T^2}{\mathrm{Ths}_2^2 + T^2} \qquad \text{(B16)}$$

$$\mathrm{TLIM}_3 = \frac{1}{1 + \exp(\mathrm{Ths}_3 - T)} \qquad \text{(B17)}$$

Temperature impacts Flage. And Cyano.
With a formulation of half-saturation.

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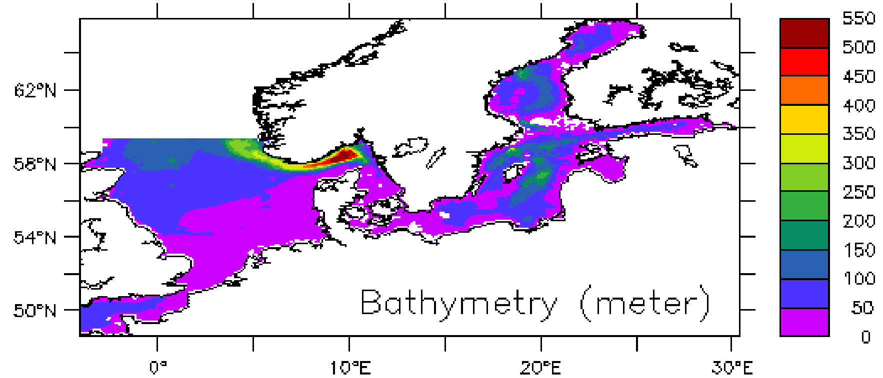
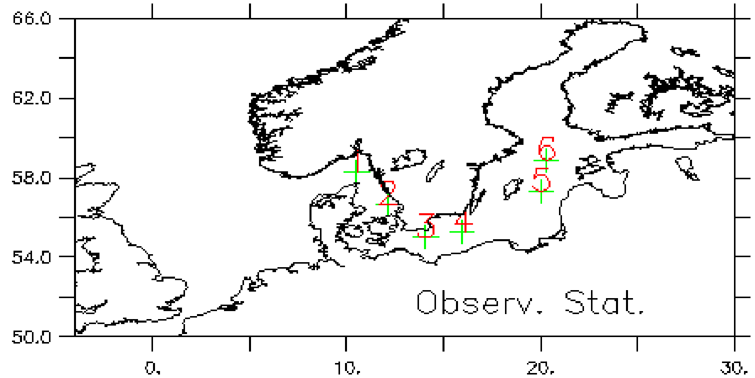
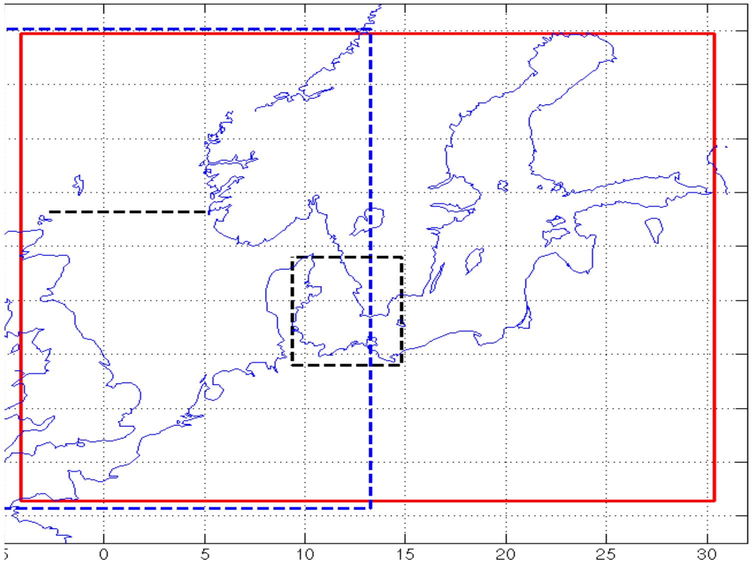
Model Domain







Model configuration

- coarse grid: 48*24'~65*54'N; 4*00'W~30*20'E; 6'x10'; 174x207
- fine grid: 53*36'~57*36'N; 9*21'E~14*50'E 1'x1.67'; 198x241
- levels: 50; thickness: 8, 2(36), 4, 8(2), 25(2), 50(8)
- initial condition: ICES data
- river loadings: SHMI model outputs and European continental river data (Germany)

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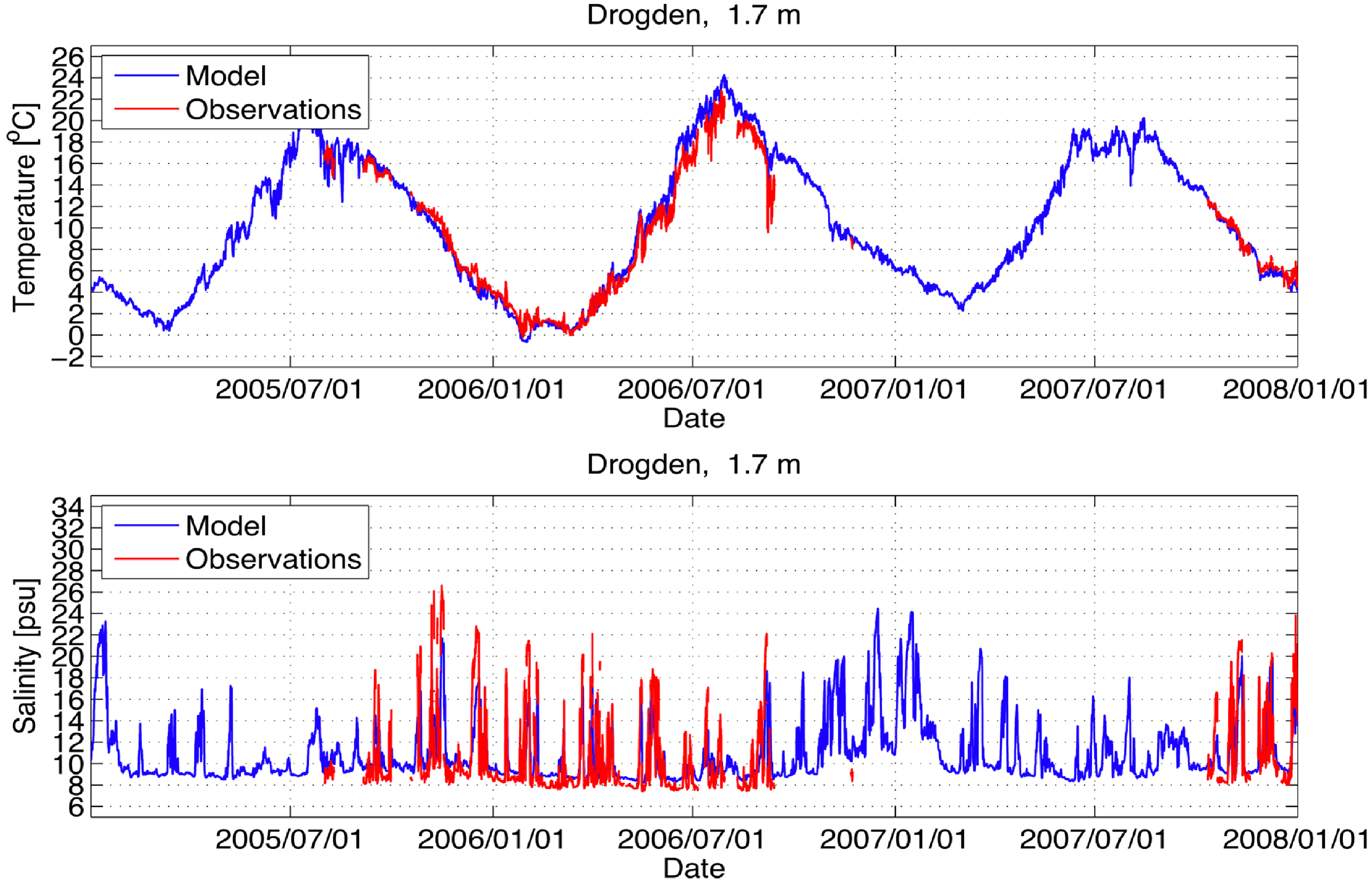
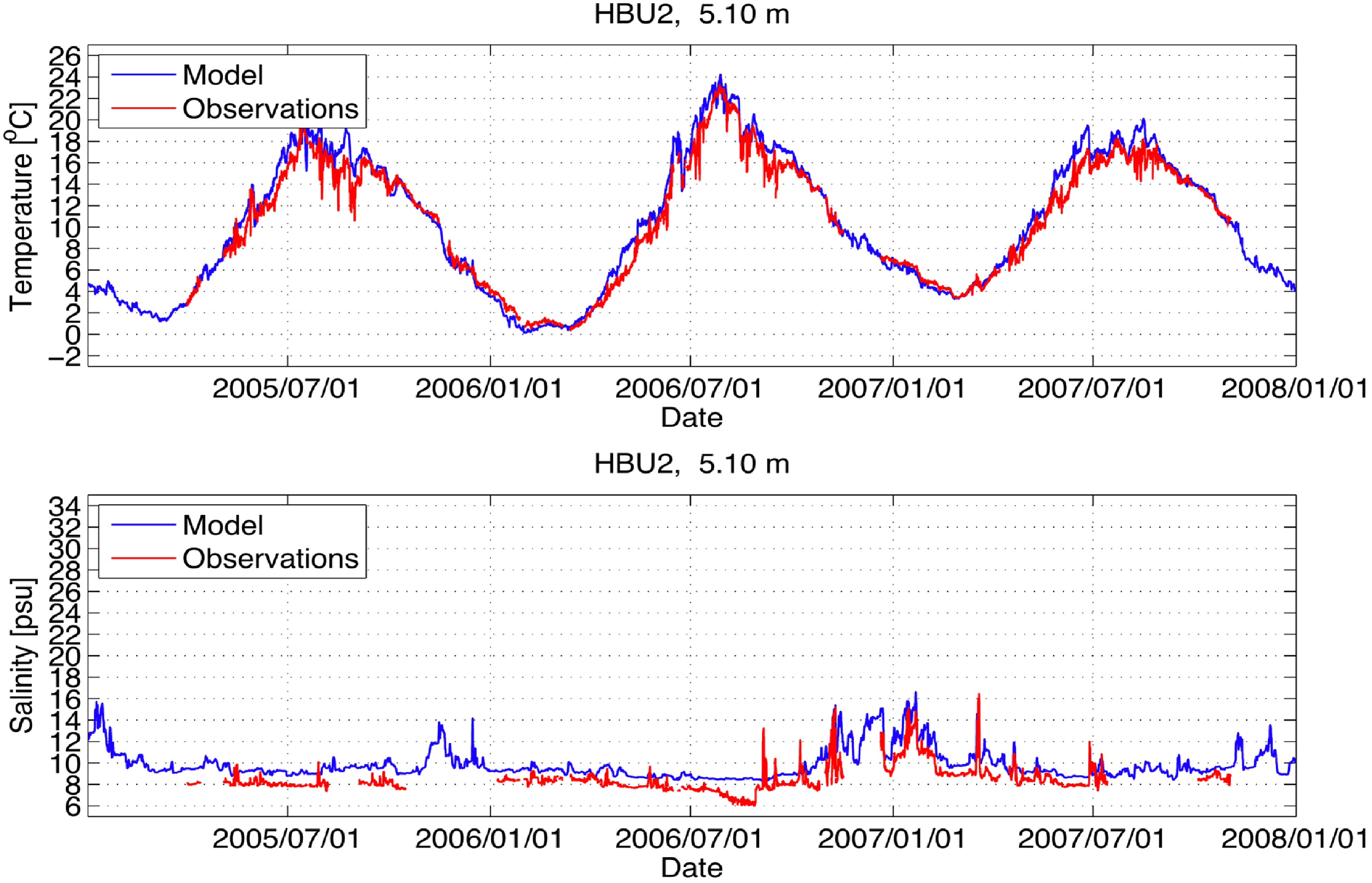
T,S Comparisons (1):



T, S Comparisons (2):



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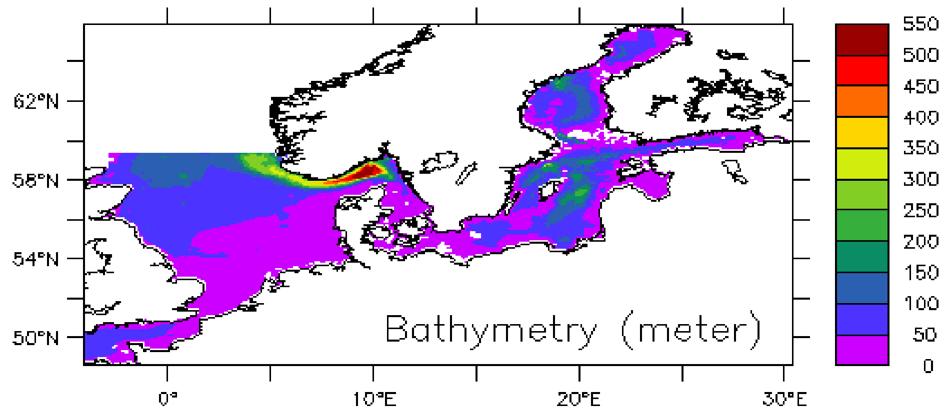
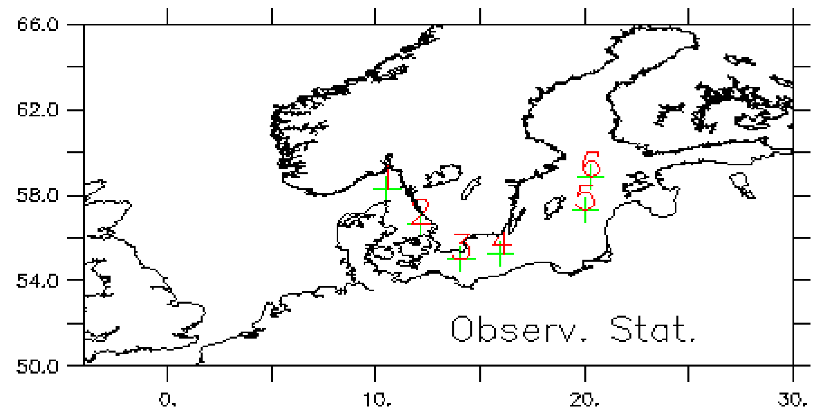
Baltic Sea Bathymetry and Observational Stations





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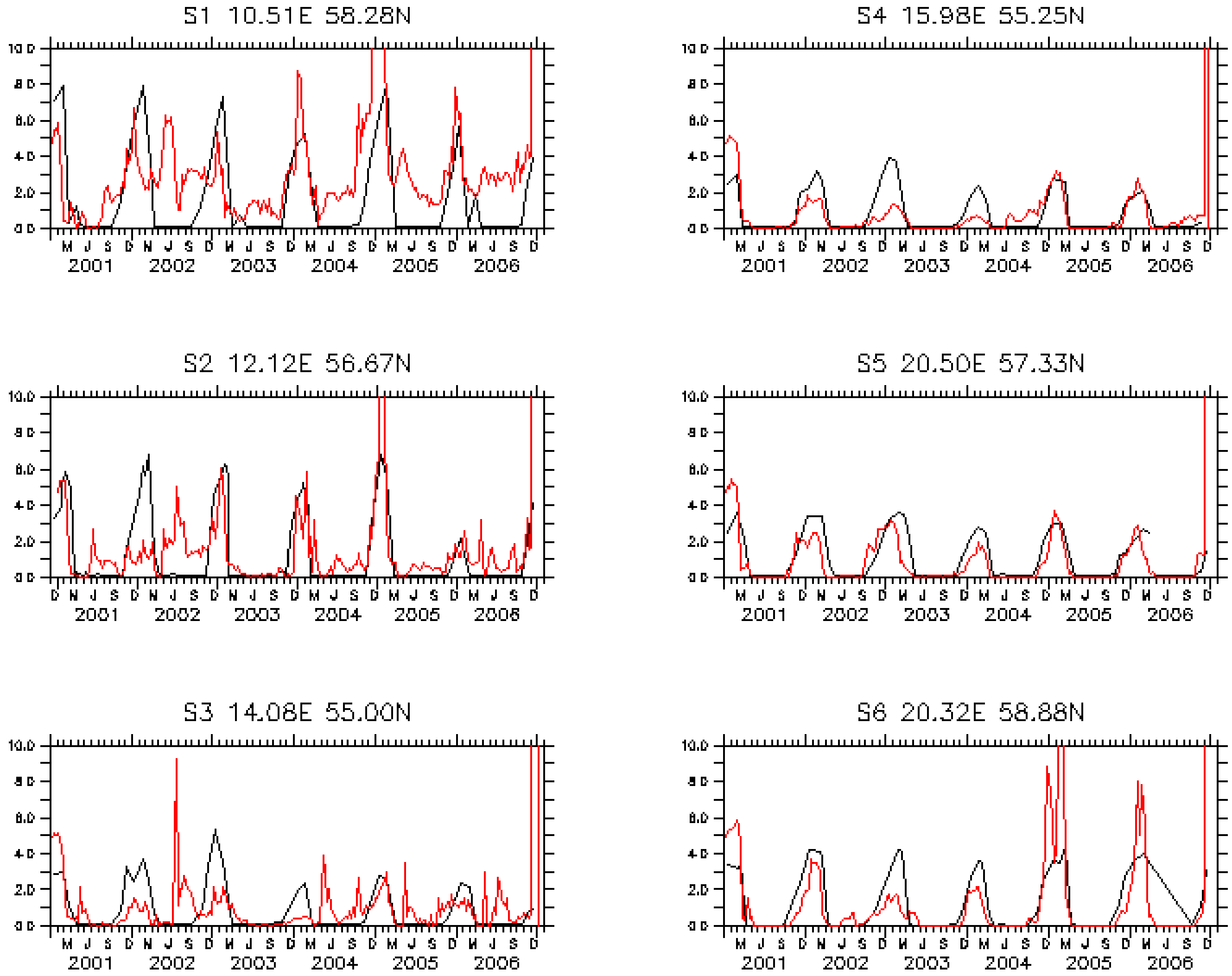
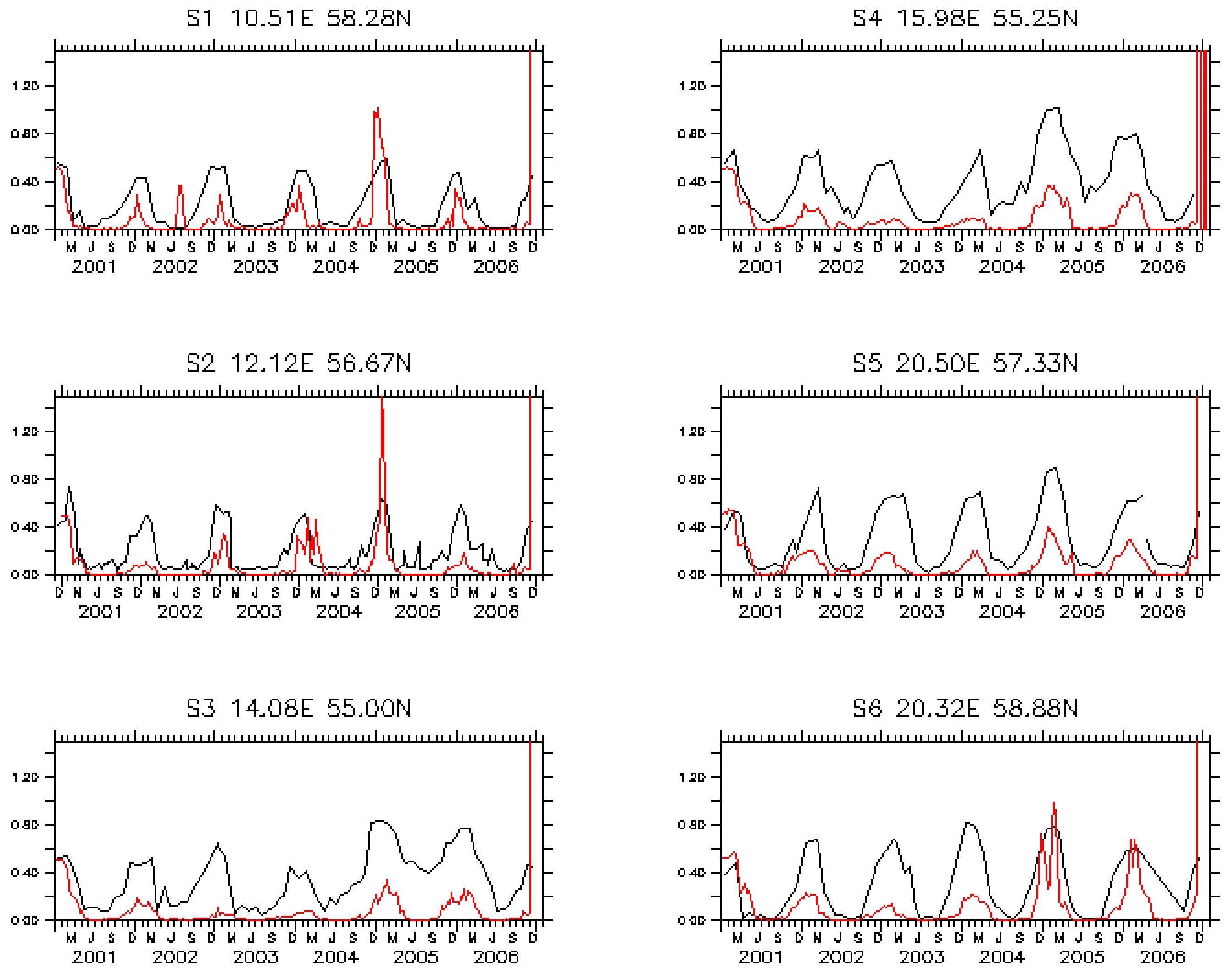
surf. no3 (umol/l); Black–Data; Red–Model



surf po4 (umol/l); Black–Data; Red–Model



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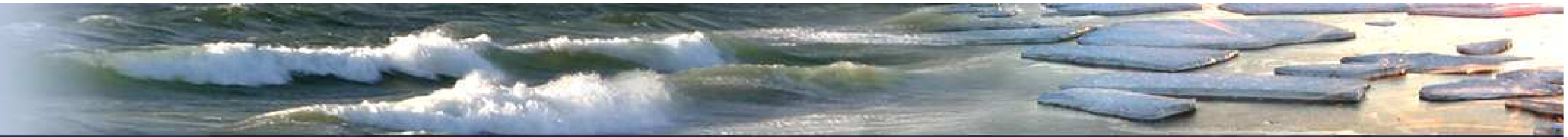
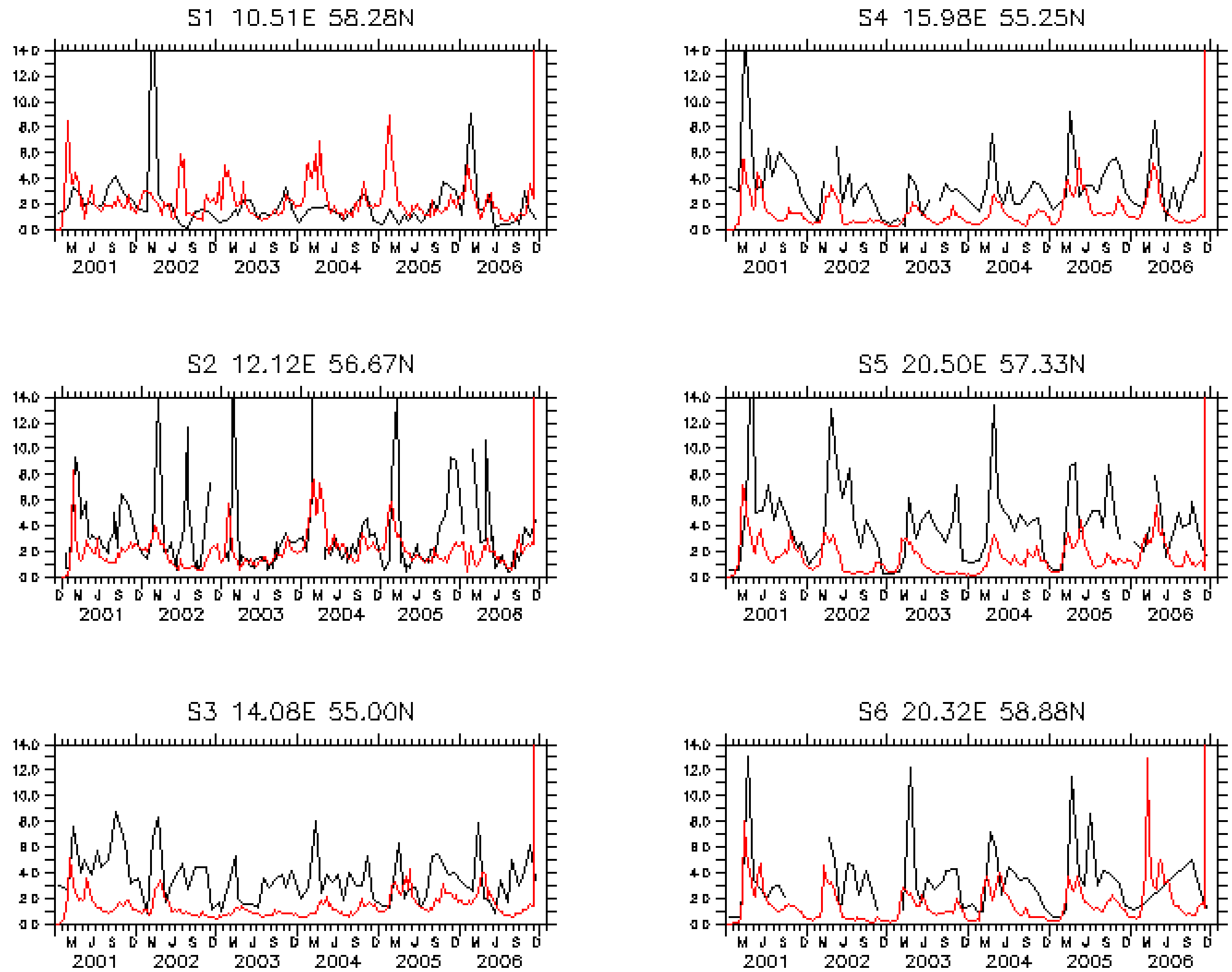
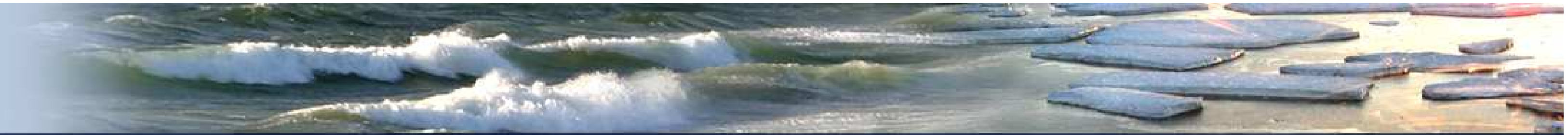
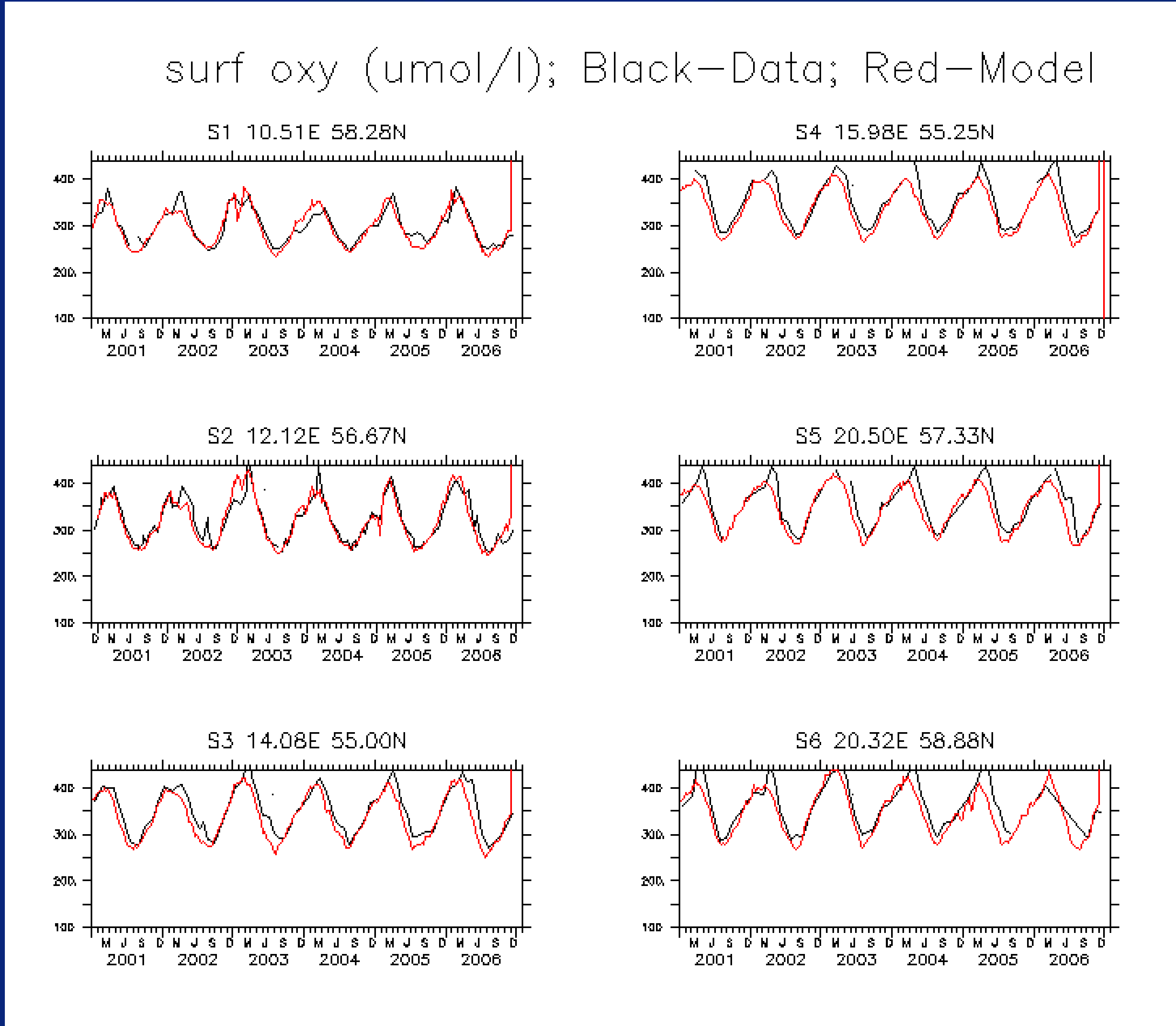


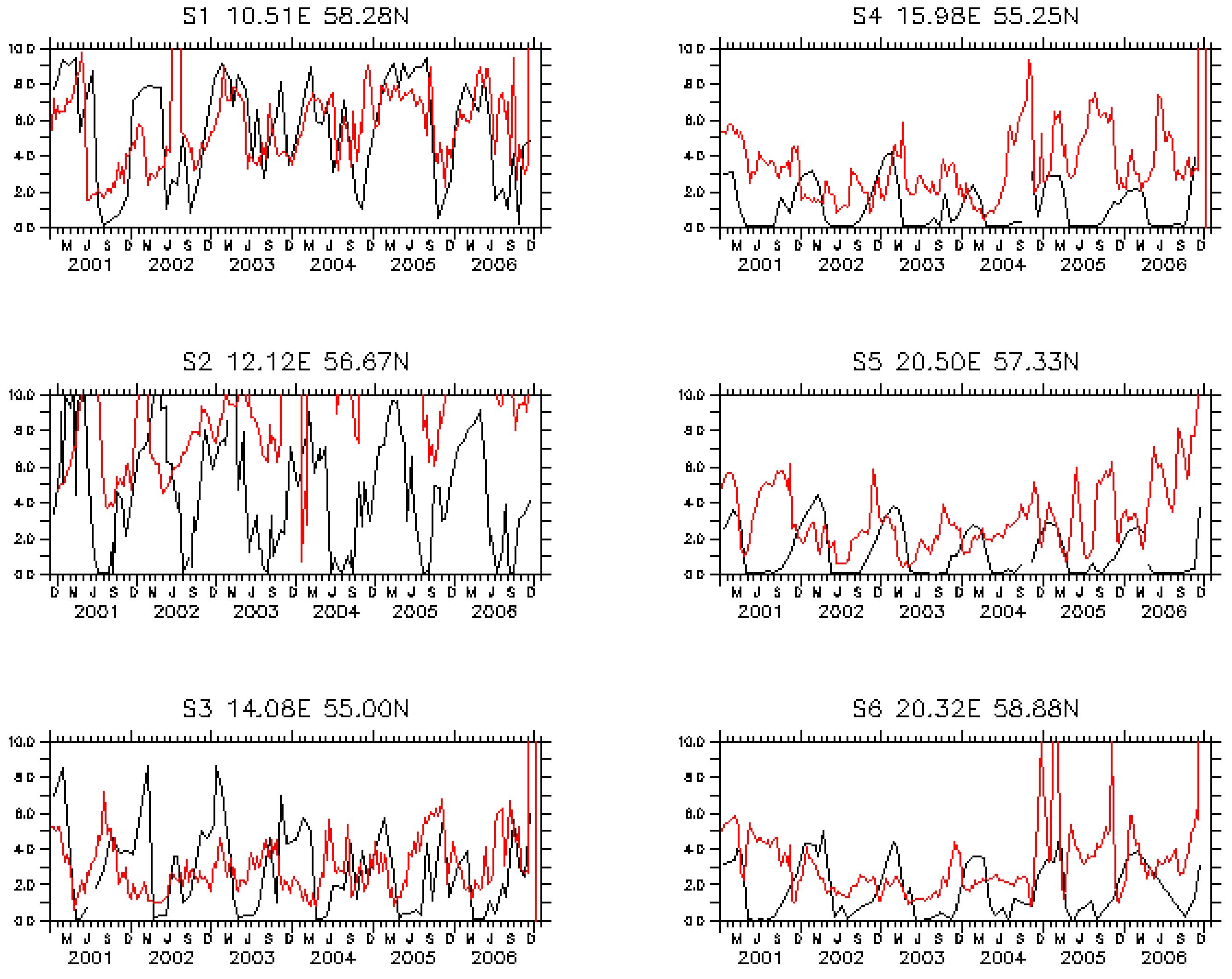
surf. chl (ug/l); Black–Data; Red–Model






surf oxy (umol/l); Black–Data; Red–Model
S1 10.51E 58.28N
S4 15.98E 55.25N
S2 12.12E 56.67N
S5 20.50E 57.33N
S3 14.08E 55.00N
S6 20.32E 58.88N
400
300
200
100
2001
2002
2003
2004
2005
2006

40m no3 (umol/l); Black–Data; Red–Model



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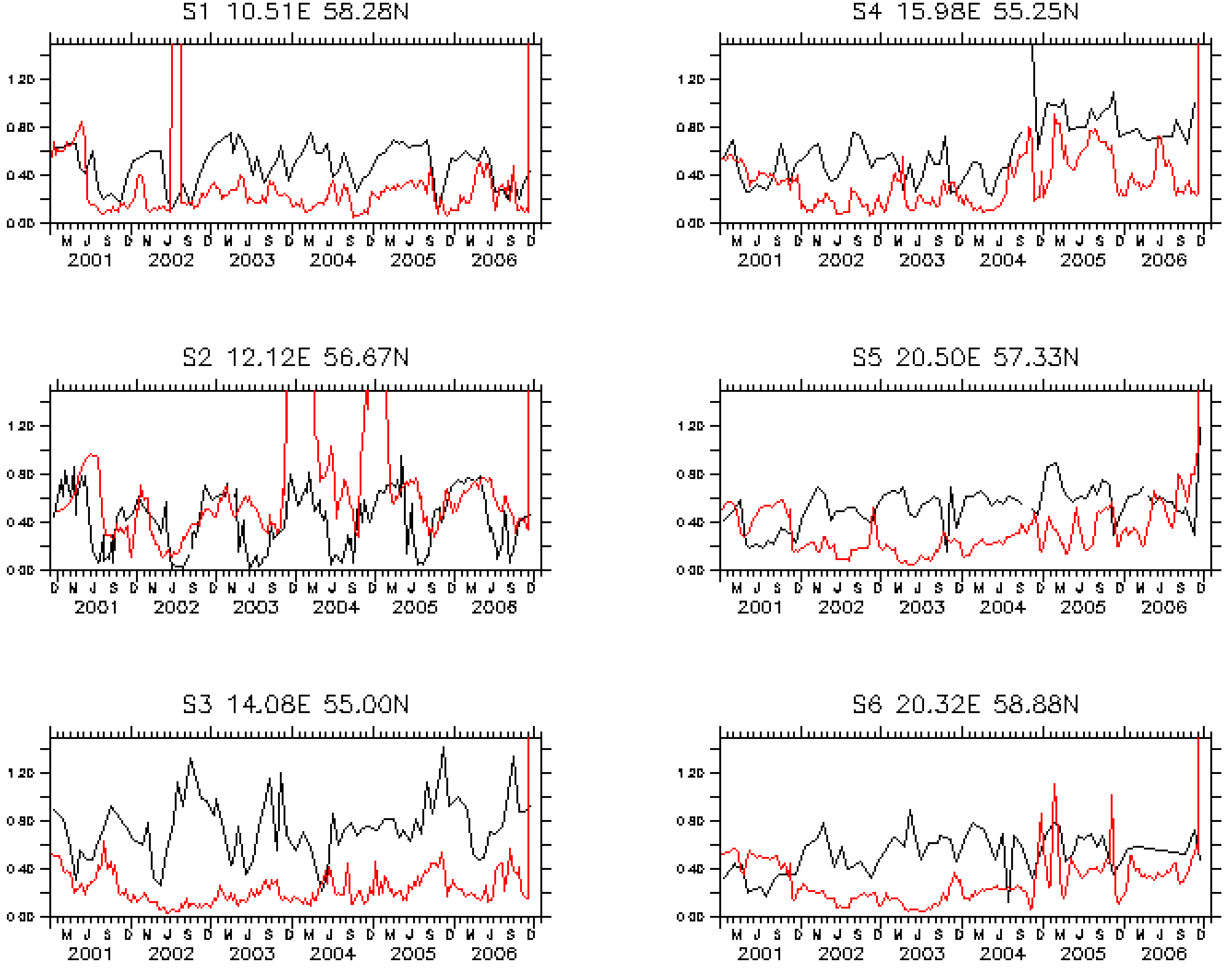
40m po4 (umol/l); Black=Data; Red=Model



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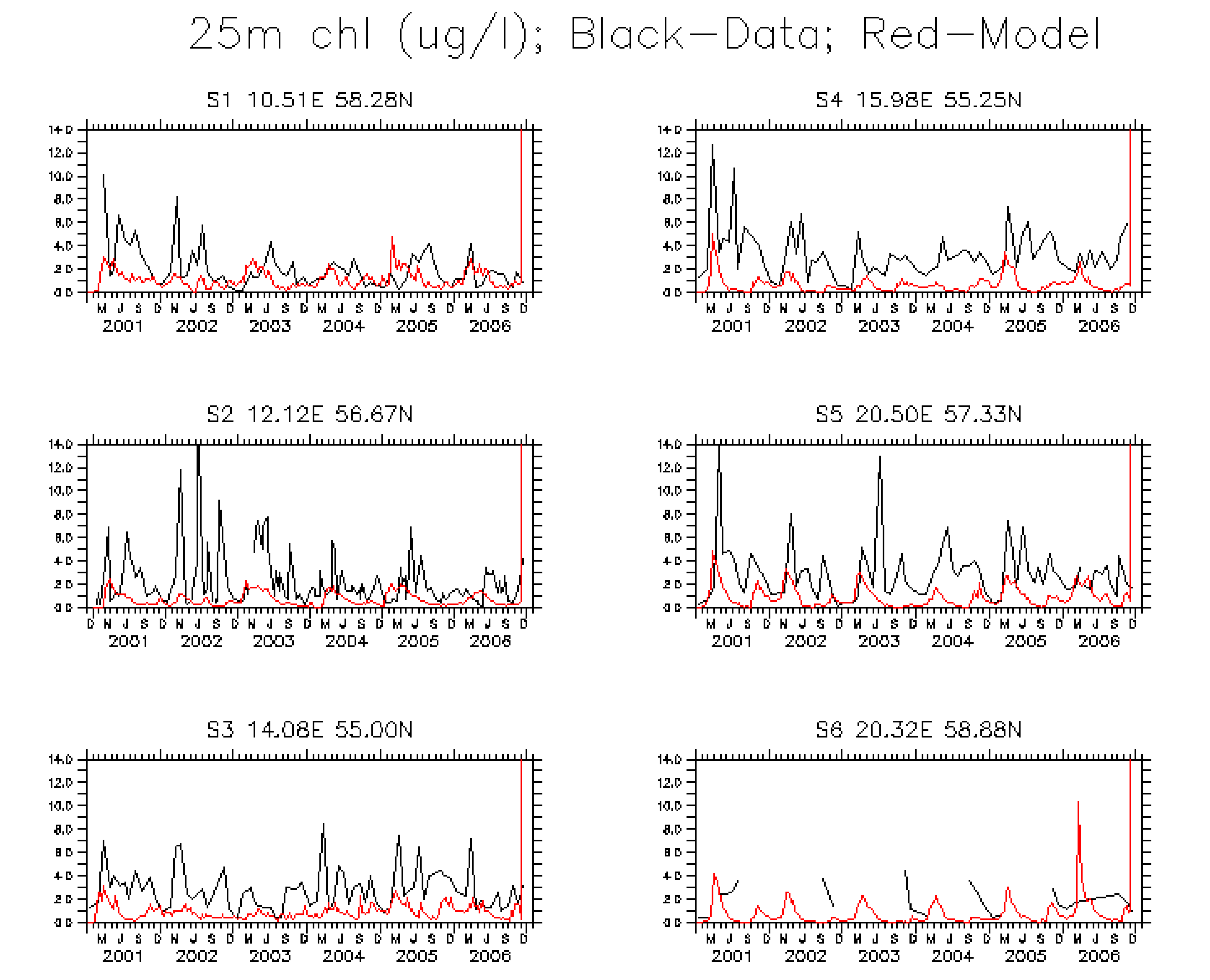
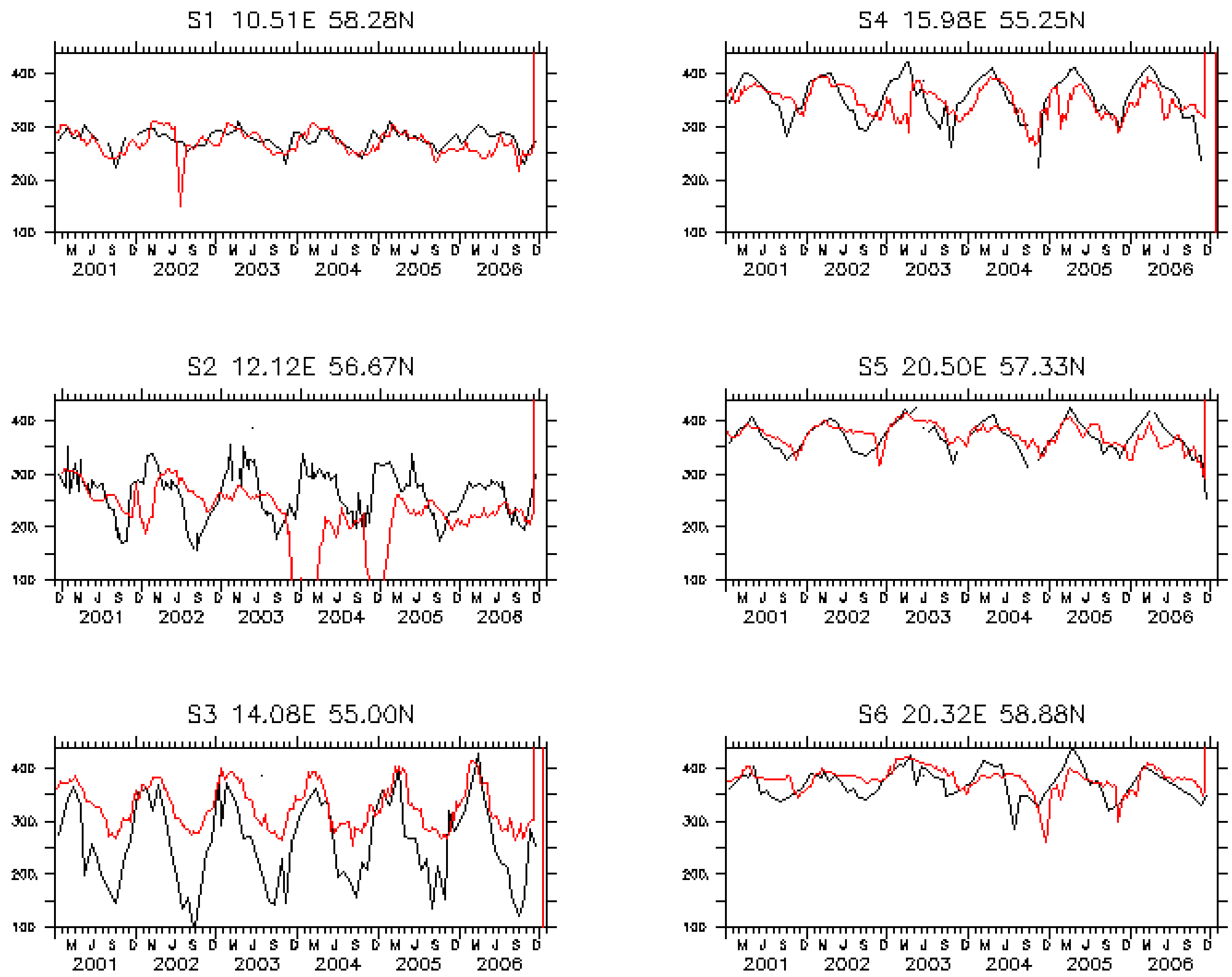


40m oxy (umol/l); Black–Data; Red–Model



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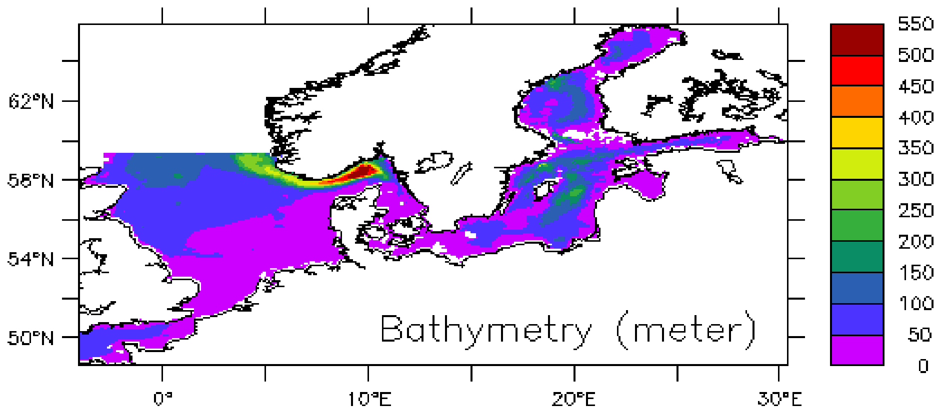
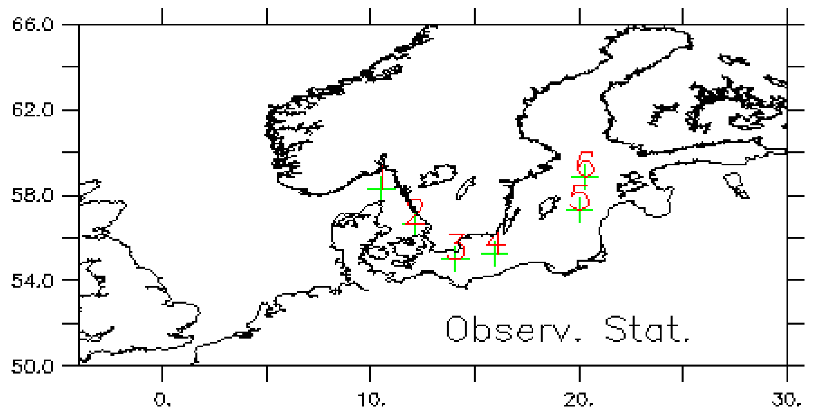
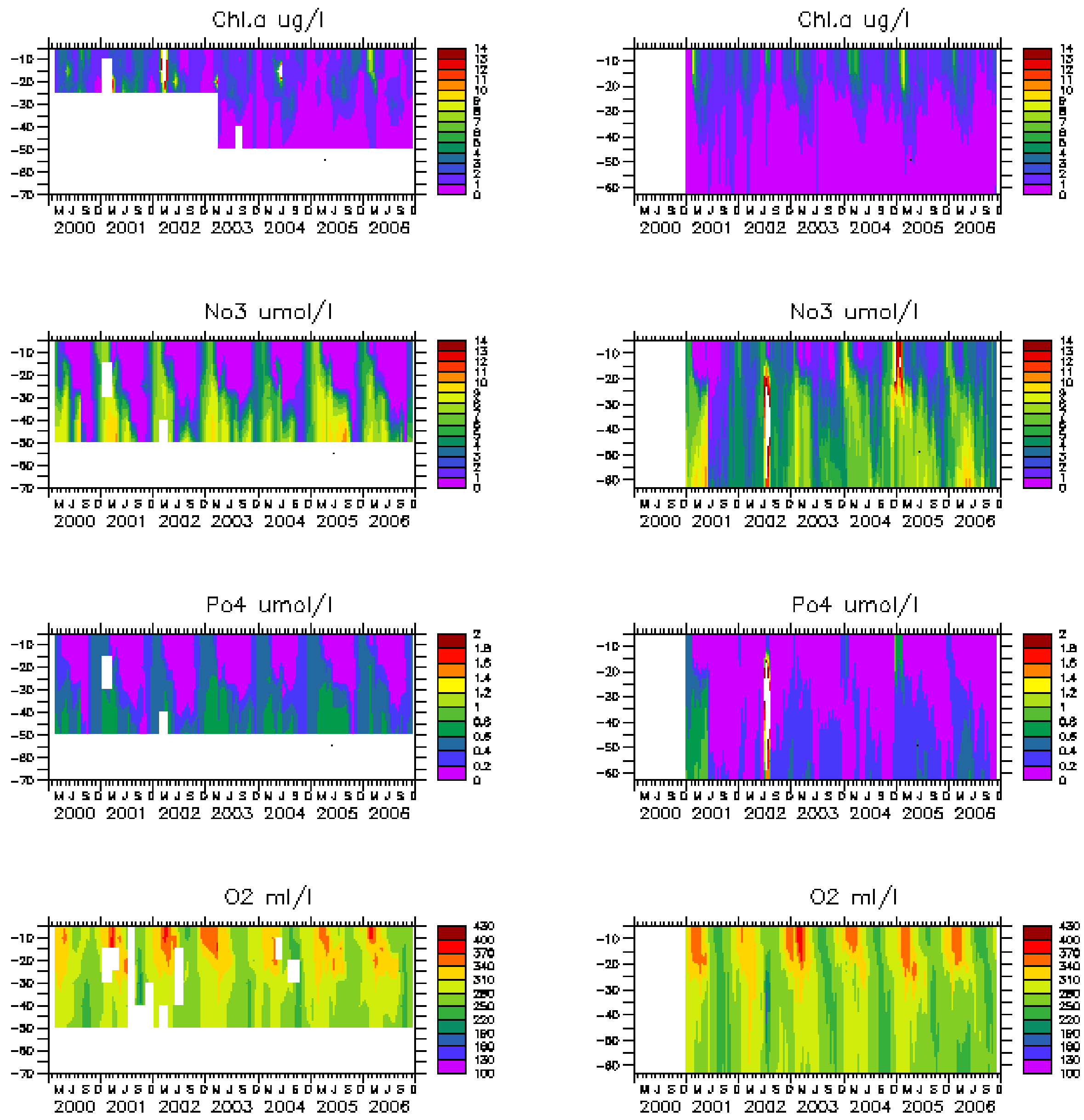
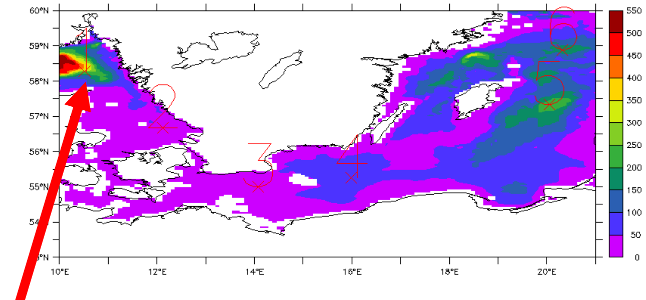
Baltic Sea Bathymetry and Observational Stations






Chl.a ug/l
Chl.a ug/l
No3 umol/l
No3 umol/l
Po4 umol/l
Po4 umol/l
O2 ml/l
O2 ml/l
2000 2001 2002 2003 2004 2005 2006



Stat. 1

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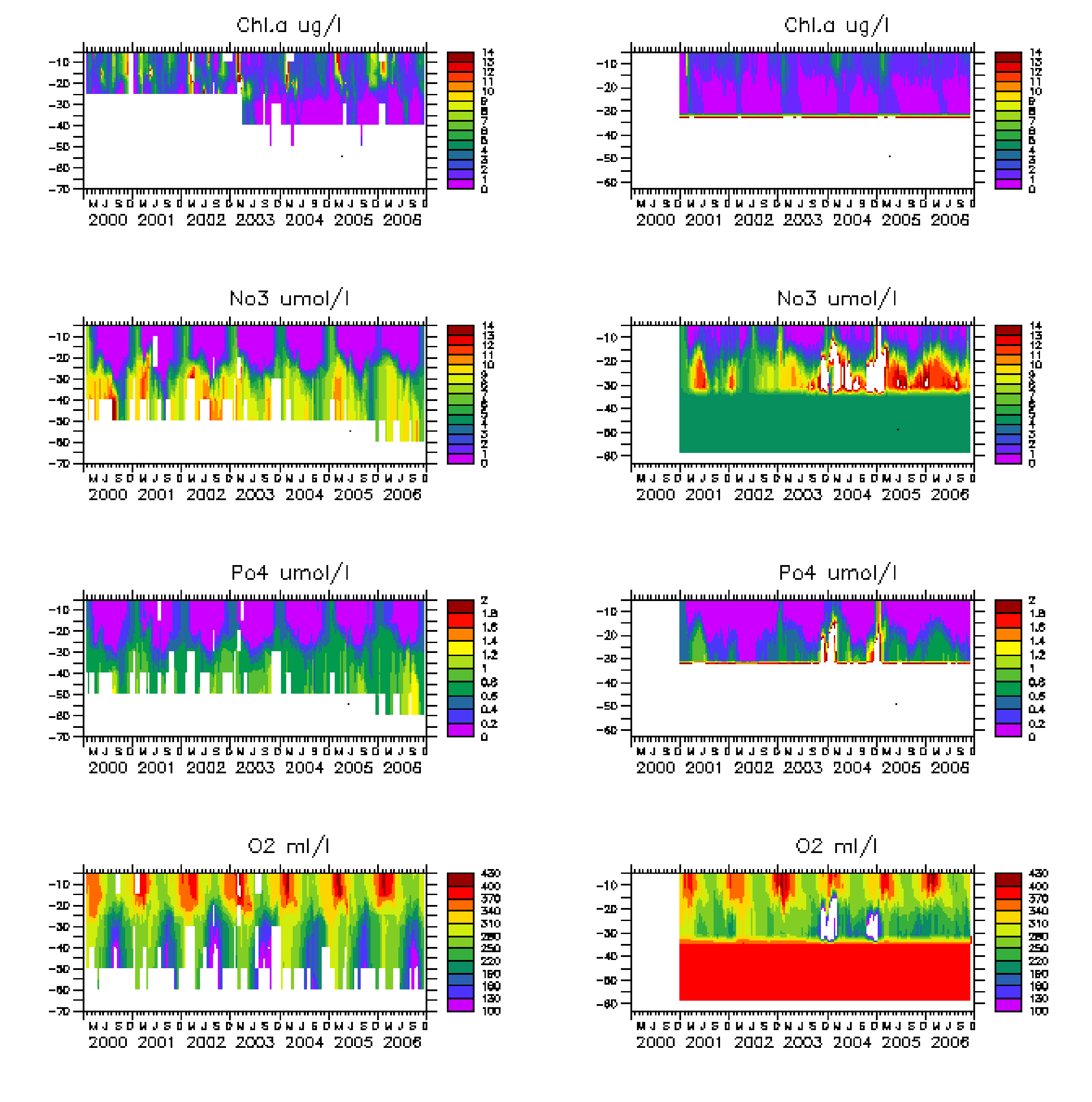

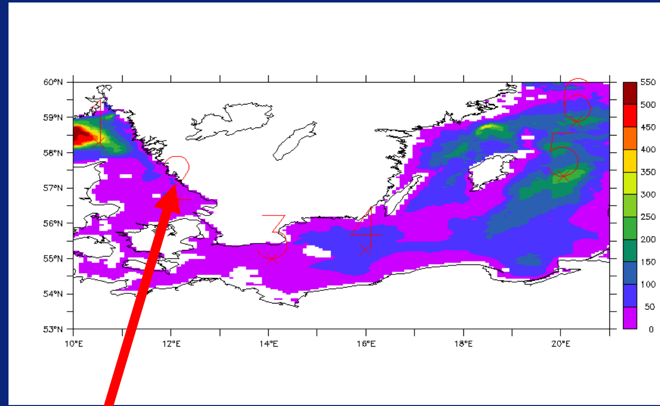

Stat. 2

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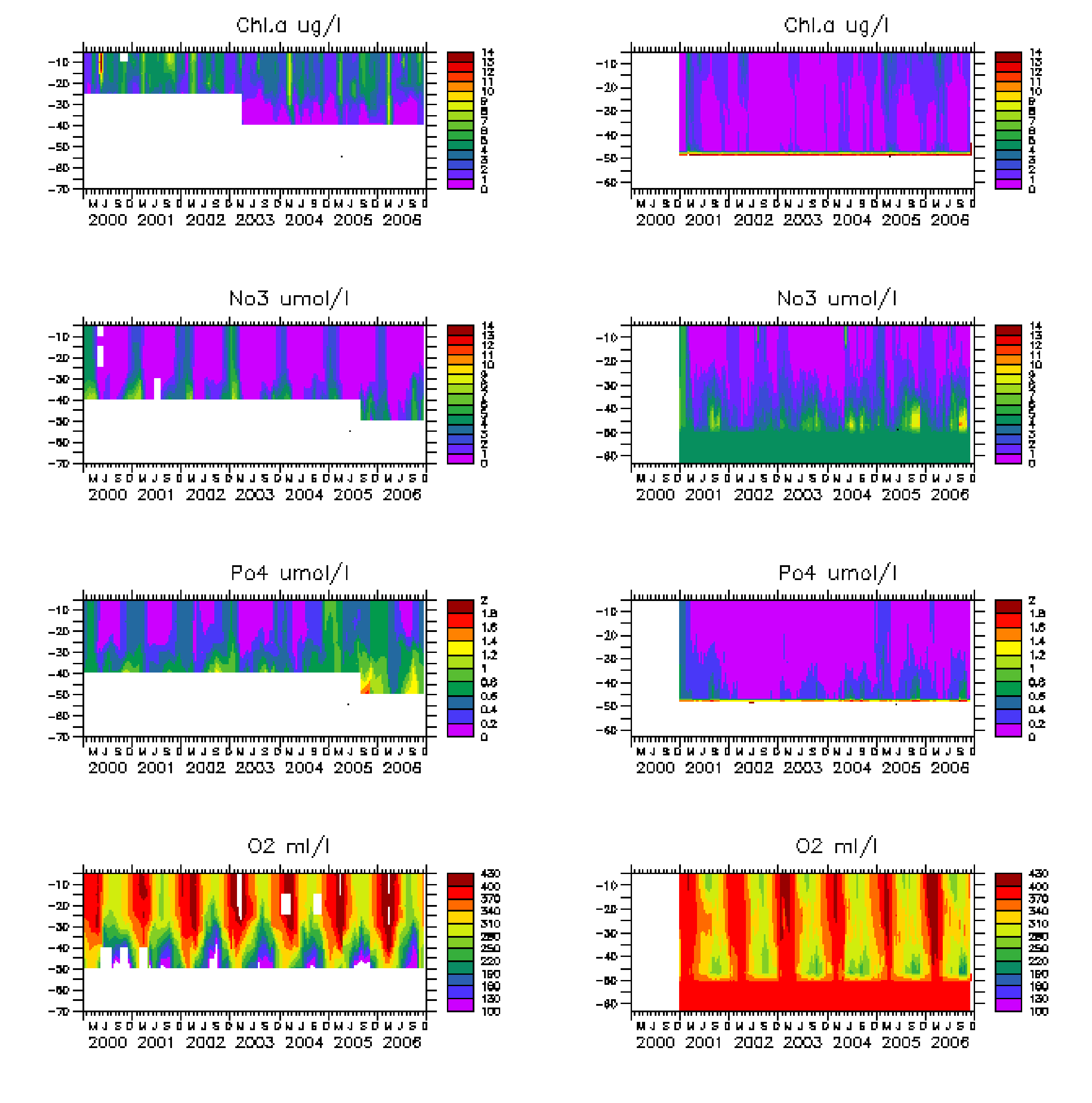

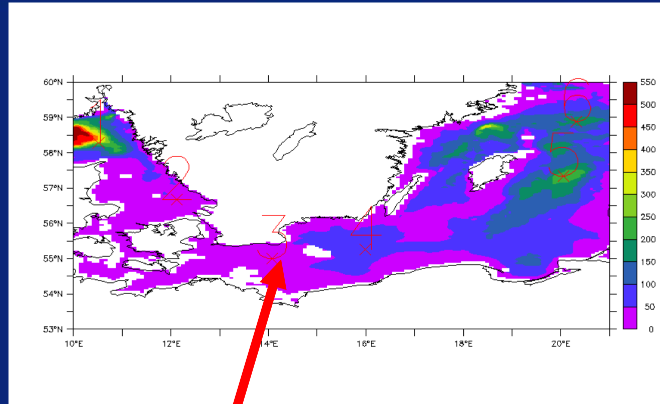

Stat. 3

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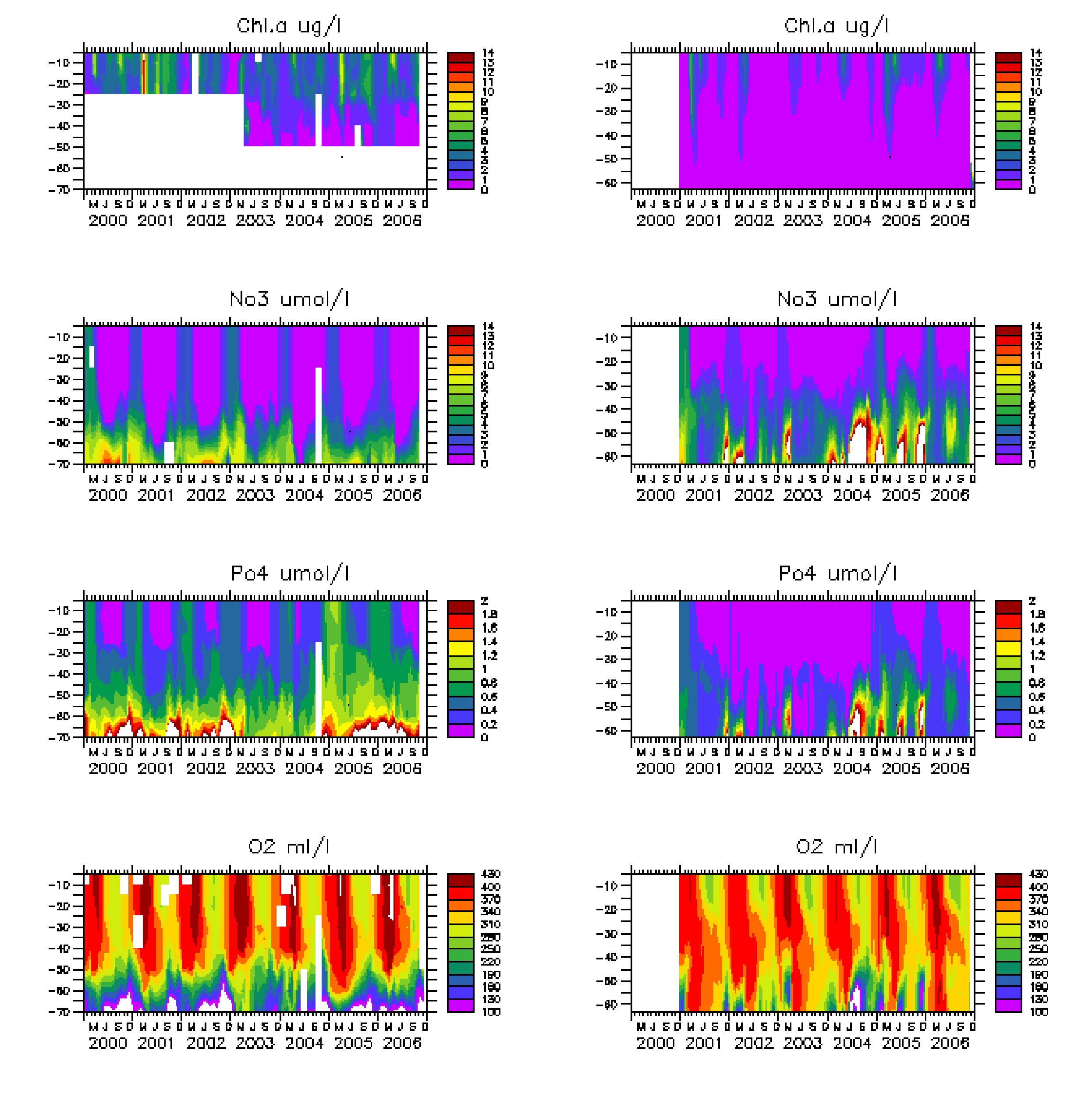

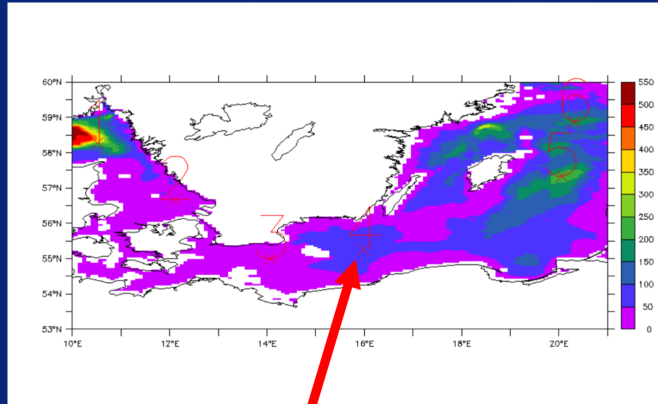

Stat. 4

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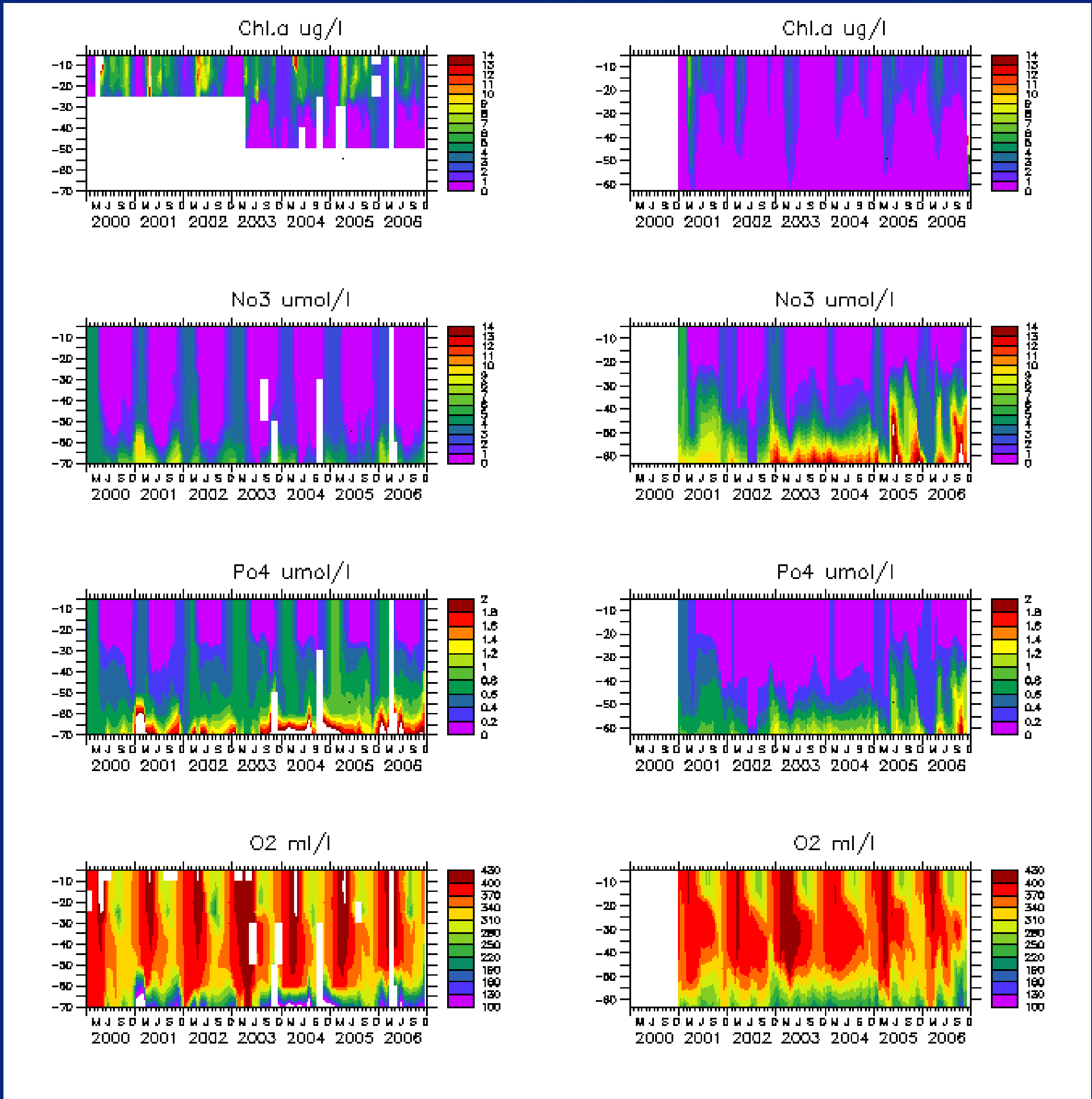

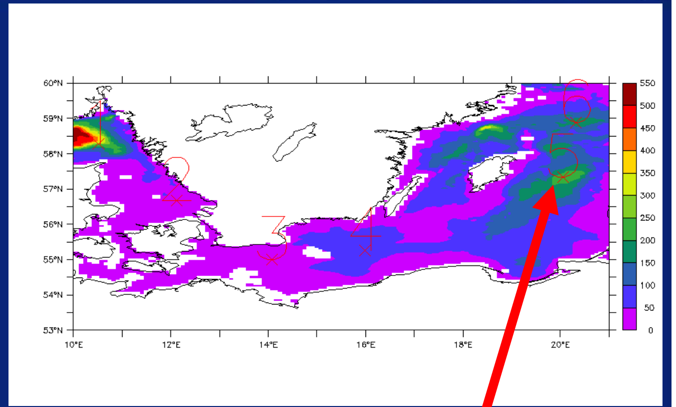

Stat. 5

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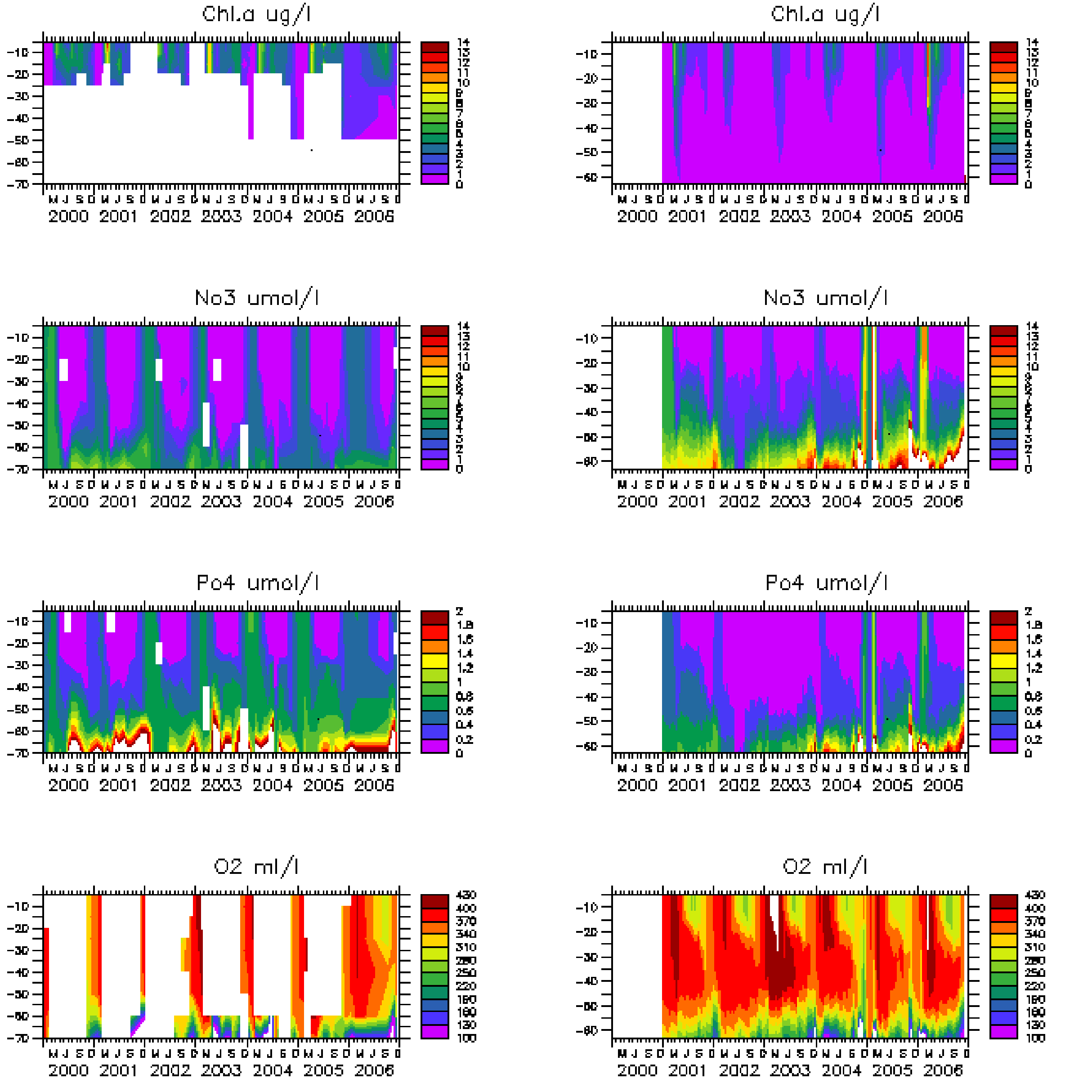

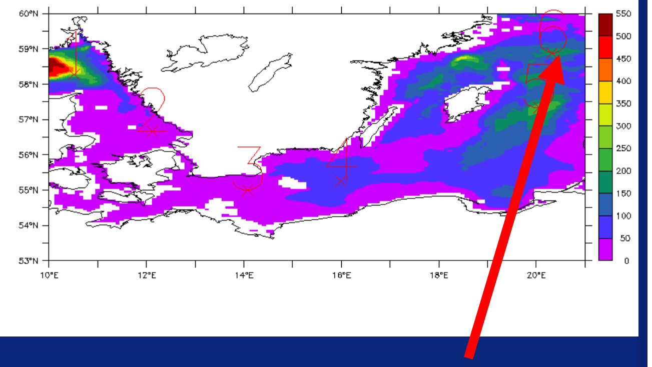

Stat. 6

Problems identified

1. The nutrients were not recovered during winter.
2. The nutrients were improperly pumped up to 30-40 meter layers in summer.
3. The phytoplankton growth were not visible so much except for Spring.

Likely causes

1. The vertical mixing was underestimated in winter.
2. The light limitation might be errorously formulated to delimit the growth in summer, or the vertical mixing was overestimated in summer

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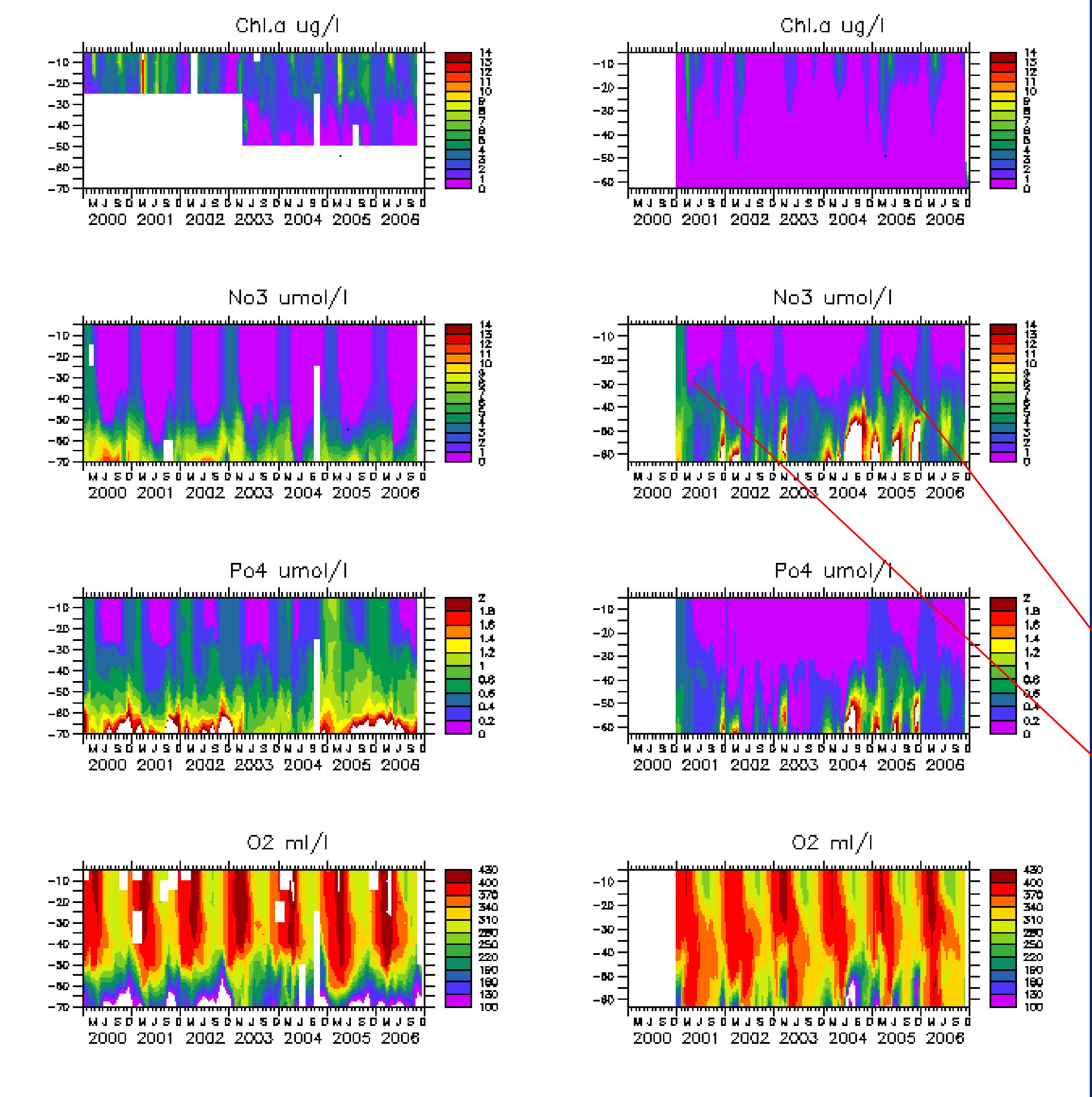
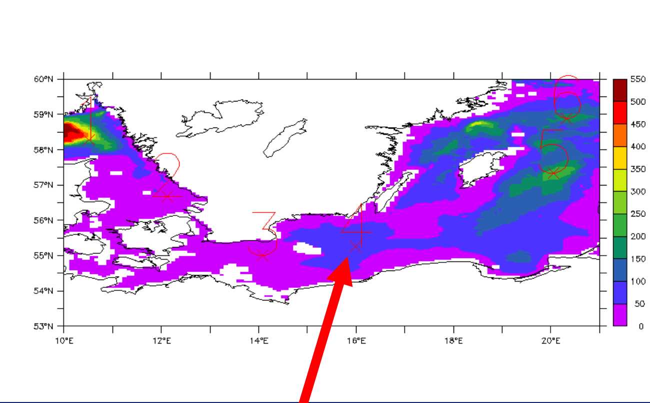
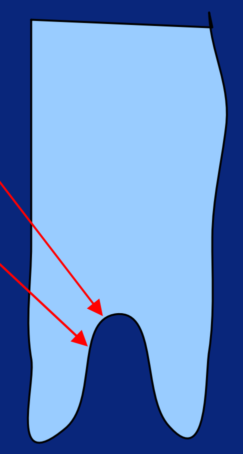
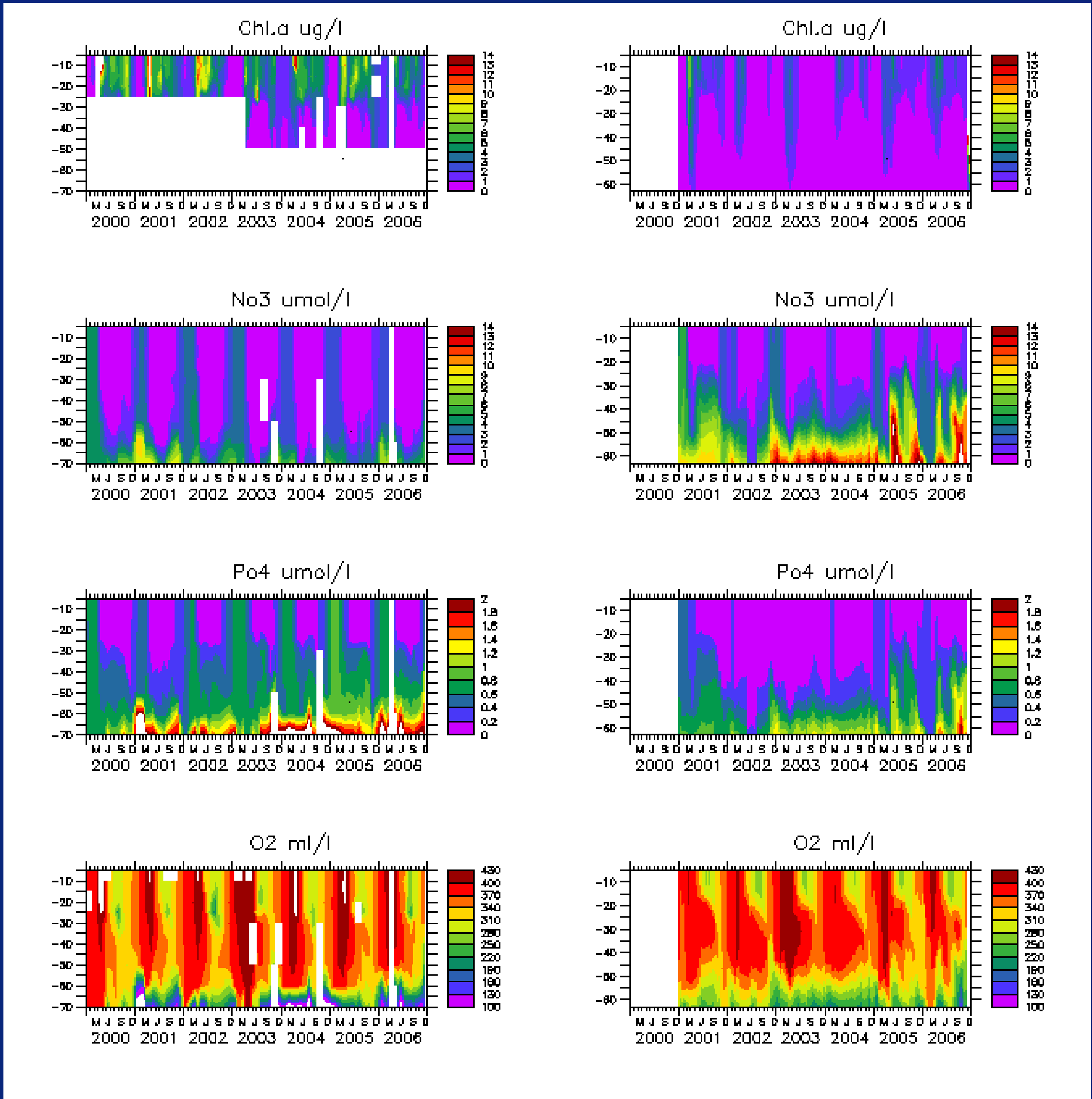
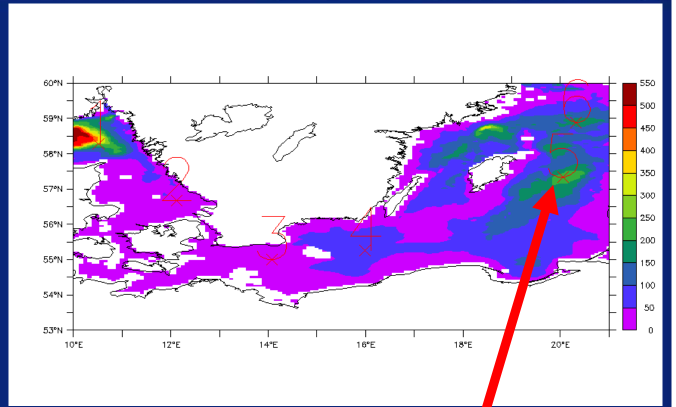




Stat. 4




Chl.a ug/l
Chl.a ug/l
No3 umol/l
No3 umol/l
Po4 umol/l
Po4 umol/l
O2 ml/l
O2 ml/l
2000 2001 2002 2003 2004 2005 2006



Stat. 5

Outlines

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Ecosystem seasonality

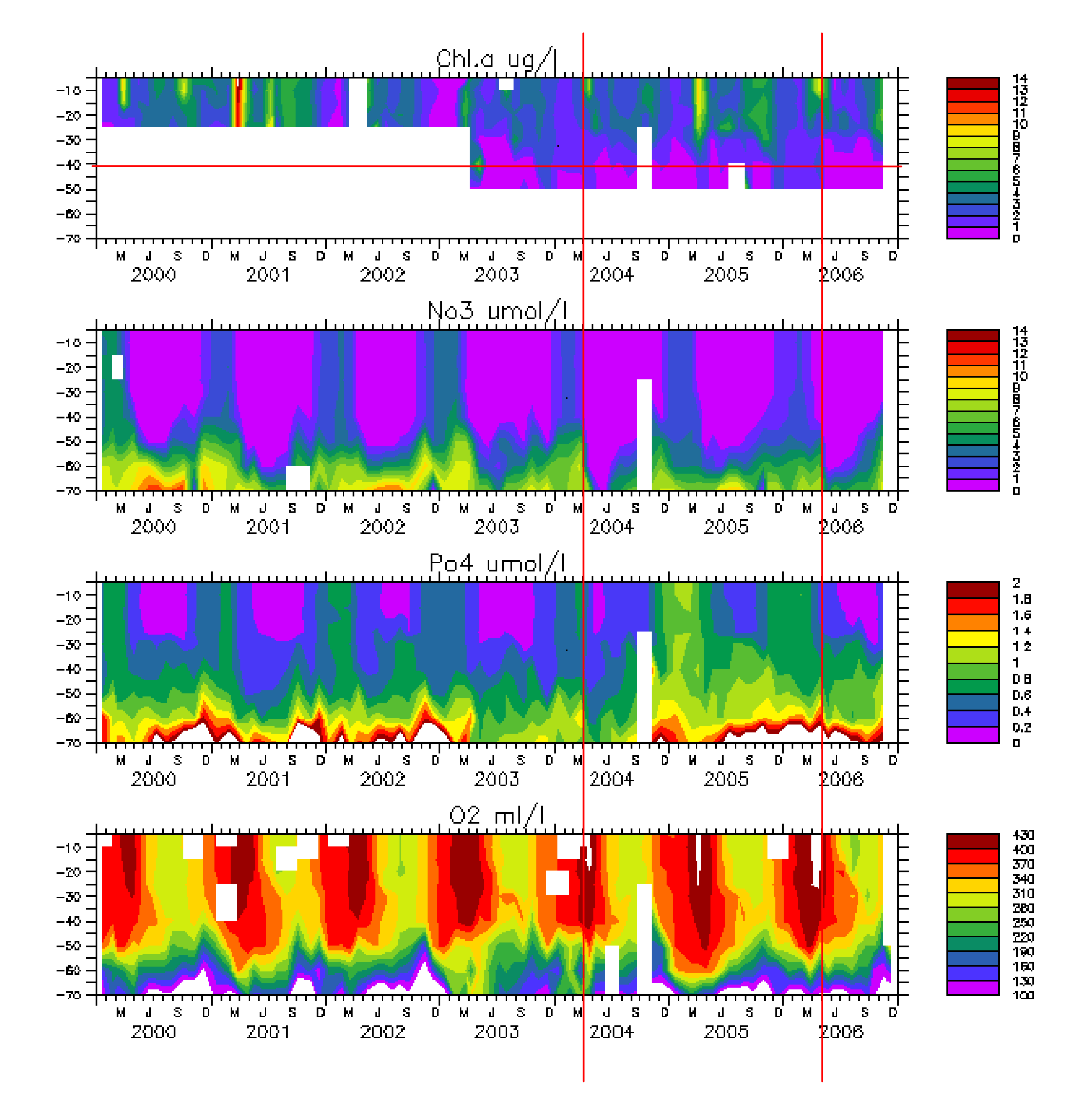
growth is limited /active

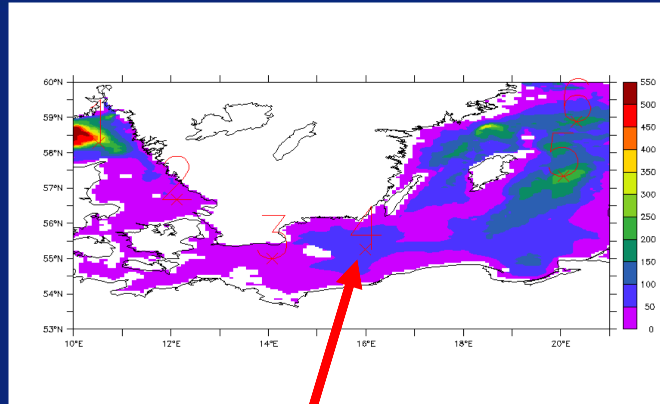
	Winter	SpringBlooming	Summer	AutumnBlooming
Diatom	L, *	******	N	N
Flagel.	L, T	T	***, N, P	**, N, P
Cyanob.	L, T	T	*, T, P	*, T, P

In winter, the growth of all phytoplankton are limited by light availability. Occasionally, when the sea water is clean up, diatom may get a chance to grow. Flagellate and Cyanobacteria may not grow with this occasional light condition, due to temperature limitation.

Soon after winter, when the insolation condition is improved, diatom grows up rapidly. Until the sea water is warmed up to suit flagellate to grow, flagellate may coexist with diatom till the nutrient is limited. Flagellate has the advantage to uptake low nutrients.

When the sea water is further warmed up to enable cyanobacteria to grow, flagellate may coexist with cyanobacteria till the nitrogen is limited. In no nitrogen condition, cyanobacteria may grow until phosphate limitation happens and/or sea water is cooled down.





Stat. 4

Why the nitrogen deficit depth is much larger than the depth where the chrolophyl is visible?

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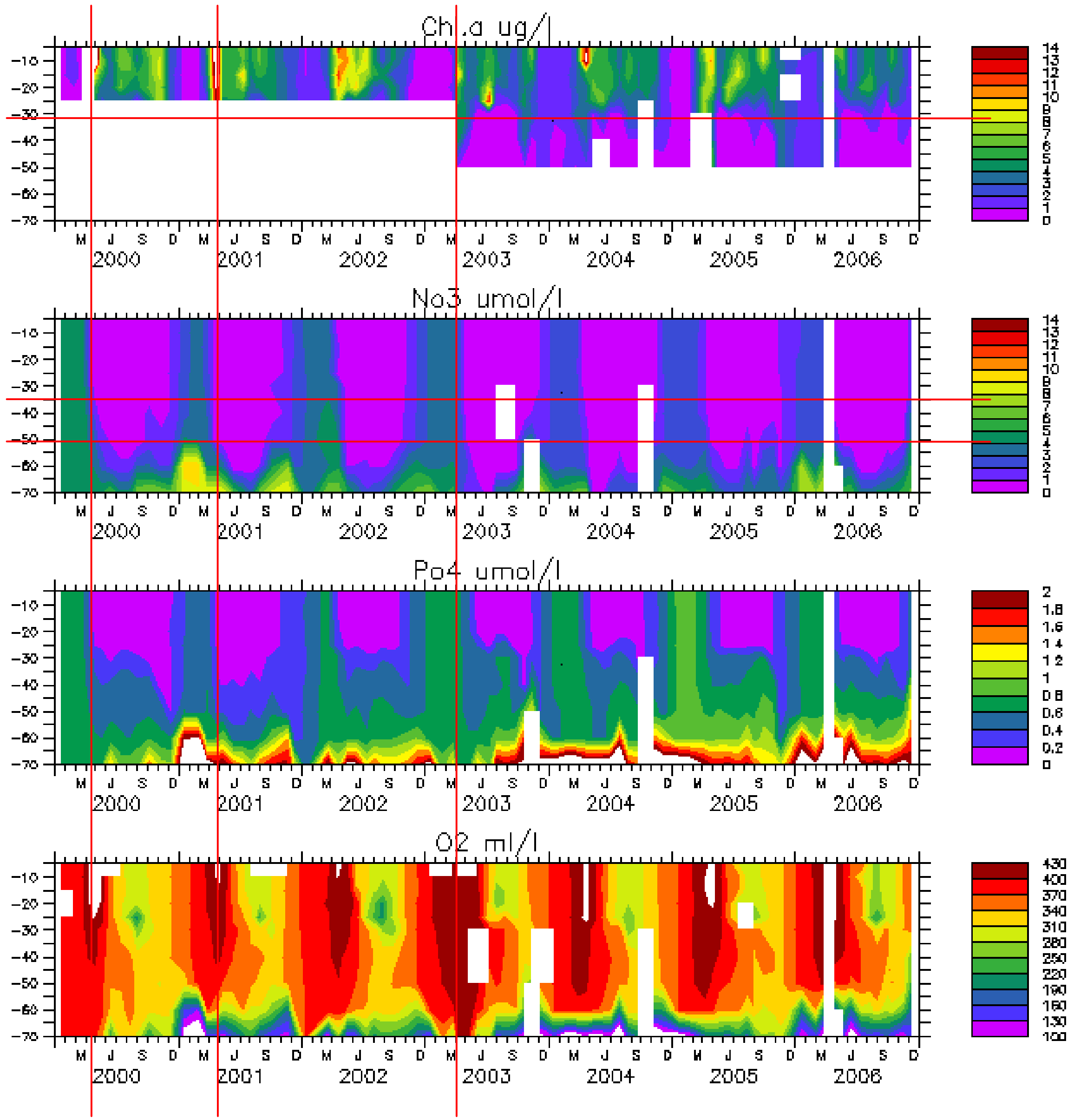
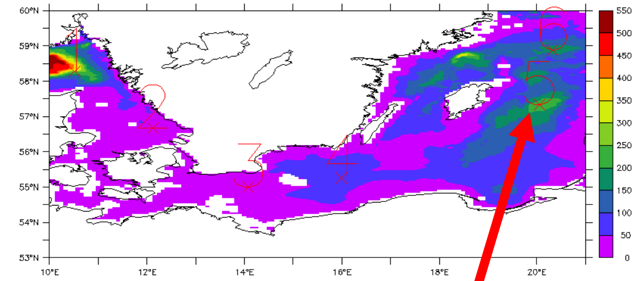




Stat. 5

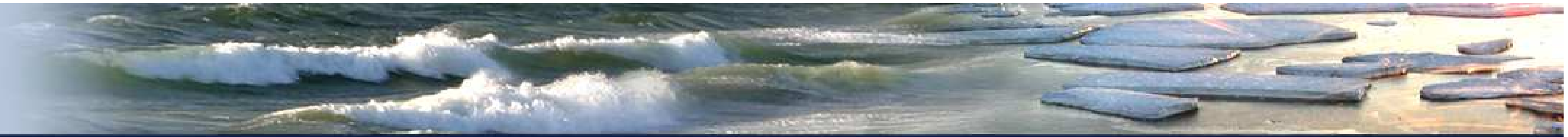
Why the nitrogen deficit depth is much larger than the depth where the chrolophyl is visible?

summary

1. A preliminary model result is presented. The problems are identified. The likely causes are exploited.

2. A seasonal availability is described on base of literatures and the experience gained in tuning model.

3. A question is raised on why the nitrogen deficit depth is much larger than the depth where the chrolophyl is visible.



Thank you!