Our reply to referee's comments is incorporated in referee's text.

General comments

The aim of the manuscript is to identify possible prerequisites, occurred in the preceding year, for explaining phytoplankton blooms in the Northern Adriatic Sea. The authors consider a long time data series from 1990 to 2004 and use PCA for detecting patterns and long term changes in phytoplankton distribution and current fields.

The authors try to reconstruct the phytoplankton blooms in the North Adriatic Sea from the combination of preconditioning factors: circulation pattern, Po river discharge, precipitation and evaporation.

The approach to integrate the forcing of some of the main drivers in order to explain the monthly variability of phytoplankton abundance is a relevant attempt towards an understanding of the phytoplankton dynamics in the Northern Adriatic sea.

Wind direction and intensity should have been taken into account in the data analysis. The absence of wind forcing is a lack as this is an important driver for the blooming of many phytoplankton species as well as for determining the stratification rupture and mixing.
Wind was included in new version of our ms. However, as wind is specific parameter with both direction and intensity, is highly variable, and induces changes in horizontal and vertical motions indirectly (via changes in air-sea fluxes of heat, moist and impulse), we analysed it in different manner than other parameters (Po discharge, circulation, fluxes), only descriptively. We state in new Introduction section:
„Wind, inducing changes in air-sea fluxes (of heat, moist and impulse), affects horizontal and vertical motions in water column indirectly. In that way winds reflect on phytoplankton abundances, dependant on sea dynamics. In order to find out whether it is possible to relate winds of certain strength and direction to increase in phytoplankton abundances we perform a descriptive analysis of winds preceding measurements of large or low phytoplankton abundances."
To broaden our discussion of the finding that evaporation intensity in month of November is related to next winter circulation patterns along with phytoplankton abundances, we analysed descriptively winds in months of November. We also analysed winds in July and February in days preceding phytoplankton samplings.
We added new section (3.6. Wind influence) in which we present results of our investigation, and new Table 3:
"*3.6.1 Wind intensity.*
In 2001, 2003, 2004, years of low evaporation, average wind speed was 4.1-4.8 m/s, while in the years of high evaporation, it was both higher, 5.0-6.1 m/s in 1998 and 1999, and lower, 3.4 m/s in 1993 (Table 3). High evaporation in 1993 occurred in conditions of very low air temperature and very high sea temperature (9.1°C and 16.4°C, respectively; values are monthly averages for three stations in the region, Trieste, Rovinj and Mali Lošinj and low when compared to 1966-1990 averages of 10.7°C and 15.8°C), implying that temperature conditions are, besides winds, an additional important factor regulating evaporation rates.
3.6.2 Wind direction.

Winds from NE are generally stronger than winds from other directions, and as they blow over land, are dry and consequently induce enhanced evaporation. Thus it is to be expected that in months of enhanced evaporation rates NE winds are more pronounced and more frequent than in months of reduced evaporation rates. On the other hand, winds from SE are blowing over sea and are moist, thus are not expected to induce the evaporation rates of same intensity as do NE winds of the same strength. In line with this expectation, in months of November of low evaporation (in 2003 and 2004), NE winds were less frequent than in years of high evaporation (in 1993, 1998 and 1999). In addition, when evaporation was low, in 2003 and 2004, winds from SE were pronounced and appeared with higher intensities than in other investigated years. However, in November 2001, characterised by low evaporation, winds from NE were very strong and highly frequent, while SE winds were weak. Presumably, low evaporation rates were in this month due to very small difference between air and sea temperature (monthly averages of air and sea temperature for Trieste, Rovinj and Mali Lošinj were 8.3°C and 11.9°C, respectively, implying that air-sea temperature difference was 3.6°C what is low when compared to 1966-1990 average of 5.1°C).

3.6.3 Wind several days prior to phytoplankton sampling.

Bora events [mostly of (E)NE direction] were observed in days preceding winter sampling of both high and low phytoplankton abundances. On 17th February 2004, the largest winter bloom of 1990-2004 period, extending over the entire Po River-Rovinj section, in conditions of "anticyclonic" circulation pattern, was documented. The Po River rates were, until the last days of the month, very low. Five days before the phytoplankton measurement, a moderate bora episode (daily average of 8.6 m/s) was observed and was followed by the winds of pronounced NW or NE component, up to 4 m/s in days before measurement. In 11 days preceding the measurement of very low winter phytoplankton abundances on 20th February 2003, wind was almost exclusively of NE direction, with speed generally over 4 m/s and reaching occasionally high values (daily average up to 14 m/s on 16th February). Po River rates were in first half of the month above and in second half of the month below the average, while the circulation on date of measurement was "cyclonic".

The largest summer bloom was documented on 8 July 1997 in conditions of high Po River discharge rates, a day after a strong WNW (5 bofors) episode, which might have helped in spreading of low salinity Po River waters from delta area towards the east. Strong winds from west (WSW 5 bofors in the morning and NNW 6 bofors in the evening), blowing in July 2001 three days before sampling of another large phytoplankton bloom on 23 presumably favoured spreading of Po River waters, whose rates were slightly above the average. Geostrophic circulation and salinity distribution on cruise dates in these two years show presence of two large gyres, in eastern and western part of the investigated area, in which low salinity water accumulated (Supić et al., 2003 for 1997 and unpublished data for 2001). However, in July 2000 in days preceding the 19 July cruise winds were of variable directions with only one more pronounced wind episode over 3 bofors (on 15 July, 4 bofors from ESE, midday). Po River rates were below the average, salinity between Po River delta and Rovinj was much higher than in 1997 and 2001 and geostrophic currents were weaker than in 1997 and 2001. Large bloom which occurred might be due to more intense vertical mixing in conditions of low stratification (sigma-t was around 25-25.5 at surface and around 28.5 at bottom, with difference between two values lower than in 1997 or 2001), which enabled rising of bottom

nutrients from sea bottom (which in that part of year accumulate near the bottom; e.g., Degobbis et al., 2000) and their use in primary production."

We comment our new findings in discussion section:

"No clear relation between phytoplankton abundances and wind intensity in days preceding measurements was observed. This is partly due to the fact that monthly sampling is to scarce to be related to highly changeable winds direction and strength. Our descriptive analysis showed that winter bora events preceded sampling of both high and low phytoplankton abundances. Winds with pronounced west component along with enhanced Po River discharge favoured presumably largest summer phytoplankton blooms. However, we also documented high phytoplankton abundance in July with low Po River discharge rates after moderate winds of highly changeable direction."

And:

„*November is a month in which drastic changes in geostrophic circulation fields can occur as was documented for 1999 (Supić et al., 2012). On the basis of case study in 1999-2002 it was hypothesised that surface geostrophic fields are reflections of the bottom density fields which are formed in the period of total pycnocline destruction. Different meteorological conditions in the autumn 1999 and 2000 were invoked in explanation of different circulation in subsequent winters. Our results, showing that large evaporation events favour cyclonic circulation (as shown in Fig. 9) is in line with this previous assumption, based on analysis in 1999-2001 interval, indicating that bora (NE) wind in autumn favours appearance of "cyclonic" and scirocco (SE) of "anticyclonic" winter circulation (Supić et al., 2012). Namely dry bora is expected to induce larger evaporation and surface heat losses than moist scirocco. However, our analysis showed that evaporative fluxes in November do not depend only on winds and that the air-sea difference play an important role in intensification/weakening of evaporative fluxes.*"

And we state in conclusions:

„*We showed that role of wind in evaporative fluxes enhancements is not straightforward as evaporative fluxes are highly dependent on other factors, e.g. air-sea difference. Role of wind was uncertain but that was partly due to unmatched sampling time frames between meteorological and sea data.*"

The title "Factor favouring large organic production" is misleading as the authors deal mainly with the normal succession of phytoplankton blooms and not with the dynamic of organic matter (dissolved and particulate) and with the balance among bioproduction, degradation, terrestrial inputs and loss by advection/sedimentation. I suggest that "Factors favouring phytoplankton blooms in the Northern Adriatic Sea" would be more appropriate.

The title has been changed to: „Factors favouring phytoplankton blooms in the northern Adriatic: Towards the northern Adriatic empirical ecological model".

The dependence of phytoplankton abundances on the interaction of some forcing occurred up to 1 year in advance is questionable as it is based also on a low (80 %) level of significance. I would suggest revising the manuscript considering only the correlations with 95 % of significance.

Although statistical significance of 95 % is commonly used, one tends to use lower significances in cases when one wants to recognise even slight indications of the factors which could induce some processes and/or impacts. For example, in previous paper (Kraus

and Supić, 2011) we based some of our findings on 80 % significant correlations, same as Zhang and Wang, 2013, who analyzed changes in North Atlantic circulation and surface temperature. We believe that in environmental investigations in which many processes interplay and affect each other even lower correlations between data points to important relations between them. We investigated numerous correlations between various environmental parameters and time lags in order to find the ones which best explains the ecosystem functioning. Found correlations of 80 % indicate we are on the right track. We would like to point out that, in our opinion, one of the most important findings of our paper is the fact that evaporation in November is correlated to phytoplankton abundance and circulation in next February, with significance between 86 % and 90 % (Fig. 10). The indication of our findings were previously presented in Supić and Vilibić, 2006 and Supić et al., 2012, where relation between autumn and next winter circulation were discussed. Furthermore, in independent research, by Santojanni et al., 2006, high correlations were observed between autumn conditions and next year anchovy stock estimate.
The discussion above is included also in new version of our ms, in discussion and conclusions.
(Zhang, L., Wang, C.: Multidecadal North Atlantic sea surface temperature and Atlantic Meridional Overturning Circulation variability in CMIP5 historical simulations, J. Geophys. Res. Oceans, 10, 118, 2013.)

Why the authors do not consider a data set updated to more recent years (i.e to 2013 or 2014?) and just re-analysis a data set already considered in a previous publication (Kraus and Supic, 2011)? If they could have a much longer time series it would be relevant to know if their findings are confirmed on a longer time scale.
We used the same data base set of 1990-2004 due to the following reasons:
- we wanted to elaborate more thoroughly the topic presented in our previous work (Kraus and Supić, 2011), so we intentionally used the same data set to perform a more complex analysis of the same data set: we investigated each month within a year (instead limiting our research to several months), we used further statistical methods - the Principal Component Analysis (which allowed us to extract the most important modes of long term changes in the circulation patterns and in phytoplankton abundance distribution in the region), and thoroughly researched the impacts of meteorological data and Po River data (to establish influences of more parameters on phytoplankton in the region),
- in the research of long term changes we find the fact that the same person determined phytoplankton, using the same methodology, is of high importance (in the following years both used phytoplankton methodology of determination and specialist changed),
- data used by Kraus and Supić, 2011, used in this paper, were thoroughly checked, even several times, so are a reliable base for correlation studies,
- in our opinion we should confirm our findings on a new data set, following chronologically this one, but not including data used here, e.g., not with the expanded version of used data set .

The authors in many part of the discussion and interpretation of their data consider the stratification conditions without analyzing or presenting any data about this relevant oceanographic feature which is important in the seasonal dynamics of the phytoplankton blooms (e.g. chapter 4.3).
We describe stratification year cycle in introduction, supported by a new figure, suppl.1:
„In general, the water column in the region is uniform in January-February, weakly stratified in March-April and November-December, and highly stratified from March to October (e. g., Supić and Vilibić, 2005; Suppl. 1).“

We also analyse correlation between stratification and phytoplankton abundance, supporting our analysis with a new figure, suppl. 2:
"Generally, there is no correlation between stratification and phytoplankton abundance (Suppl. 2). However, exceptionally intense stratification at the eastern part of the profile (SJ107) in February and October seems to be correlated with increased phytoplankton abundance (Suppl. 2.a). On the contrary, at the western part of the profile (SJ108) such correlation was not observed (Suppl. 2.b)."

Finally we discuss the obtained results:
"Only sporadic correlation were observed between phytoplankton abundances and stratification degree, meaning that wind induced vertical mixing in water column does not induce large phytoplankton abundance."

And conclude:

"*In addition, it seems that wind induced vertical mixing in water column does not necessary reflect on large phytoplankton abundance as stratification degree, when analysing data separately for each month, was only sporadically related to phytoplankton abundances."*

Minor comments
P. 1220, L. 6 I suggest to avoid "at the transect" as it is not clear and it is not necessary to outline the sampling strategy in the abstract.
Done.

P.1220, L.23. A reference supporting that the North Adriatic is the one of most productive regions in the Mediterranean sea, would be useful.
Done. Included reference: Sournia, 1973.

P.122, L.20. The authors cite Krajcar 2003, but these features were described well in advance by Franco and Michelato (1992) and by Cushman Roisin et al. (2001).
Done. Suggested references included.

P.1221, L. 29. The appropriate term to use is "organic matter" and not "organic materials".
Corrected.

P.1222, L. 23. I suggest specifying "marine" environment.
Done.

P.1222, L.25 I suggest to simplify the sentence substituting "as it is the change in the Ionian Sea circulation" with: "as the inversion of the Ionian Sea circulation"
Done.

P.1227 L. 21. I suggest to write in extenso the title of the chapter : the ICCC.
Done. Title is changed to: „3.1.2 The Istrian Coastal Countercurrent – ICCC".

P.1231, L. 6, L.9. Correct "precondited" with "preconditioned".
Corrected.

P1233, L. 3. Unclear what is "February C1".

Abbreviation PA was completely removed from ms as it was used only in caption of Table 1. We used "phytoplankton abundance" throughout the entire ms.
***In order to have a more understandable abbreviations, instead of* C1 *and* F1 we use several new abbreviations:**
<u>xPC1</u> – *for the first main component of PC1 analysis performed on the inter-annual changes in: surface geostrophic currents relative to 30 m between the six stations of the Po River – Rovinj profile (<u>cPC1</u>), phytoplankton abundance - original values (<u>pPC1</u>) and log transformed values (<u>lpPC1</u>).*
<u>xPCA</u> – *for PCA scores resulting from the PCA analyses on inter-annual changes in: surface geostrophic currents relative to 30 m between the six stations of the Po River – Rovinj profile (<u>cPCA</u>), phytoplankton abundance - original values (<u>pPCA</u>) and log transformed values (<u>lpPCA</u>).*

P.1233, L. 6. I suggest to substitute "is felt at the eastern part" with "it reaches the eastern part".
Substituted.

P.1234, L.12. and L.13. I suggest to substitute "high freshwater pressure" with "high freshwater discharge".
Substituted with: „high freshwater influence", also in lines 15 and 17.

P.1235, L. 2. What do the authors mean for "more dynamic years"?
Done, changed to „when winds are more frequent and stronger".

P. 1236, L. 13. I suggest to substitute "more often winter anticyclonic circulation" with "more frequent".
Done.

P. 1236, L. 20 "and give more support our findings" insert "to" before our findings.
Done.

P.1241. Table 1 Caption. What is PA sampling? For the comments about the too low significance of 80% see the general comments,
„PA" is substituted with „phytoplankton".

P. 1249. Figure 1. Caption. Map of the northern Adriatic. I suggest to add "Sea" after Adriatic.
Done.

P.1255-6. Figure 5 and 6. Captions. Correct "1989-2014" with "1989-2004".
Corrected.

P.1257. Figure 7. The numbers on the contour levels are unreadable. Please enlarge the character.
We removed the contour levels completely, as there is a legend beside the figure.

P.1262. Figure 10. It would be useful to show also the significance of the regression lines.

Done.

Please find changed and additional tables and figures attached:

- Table 3. (new table)

- Suppl. 1. (figure)

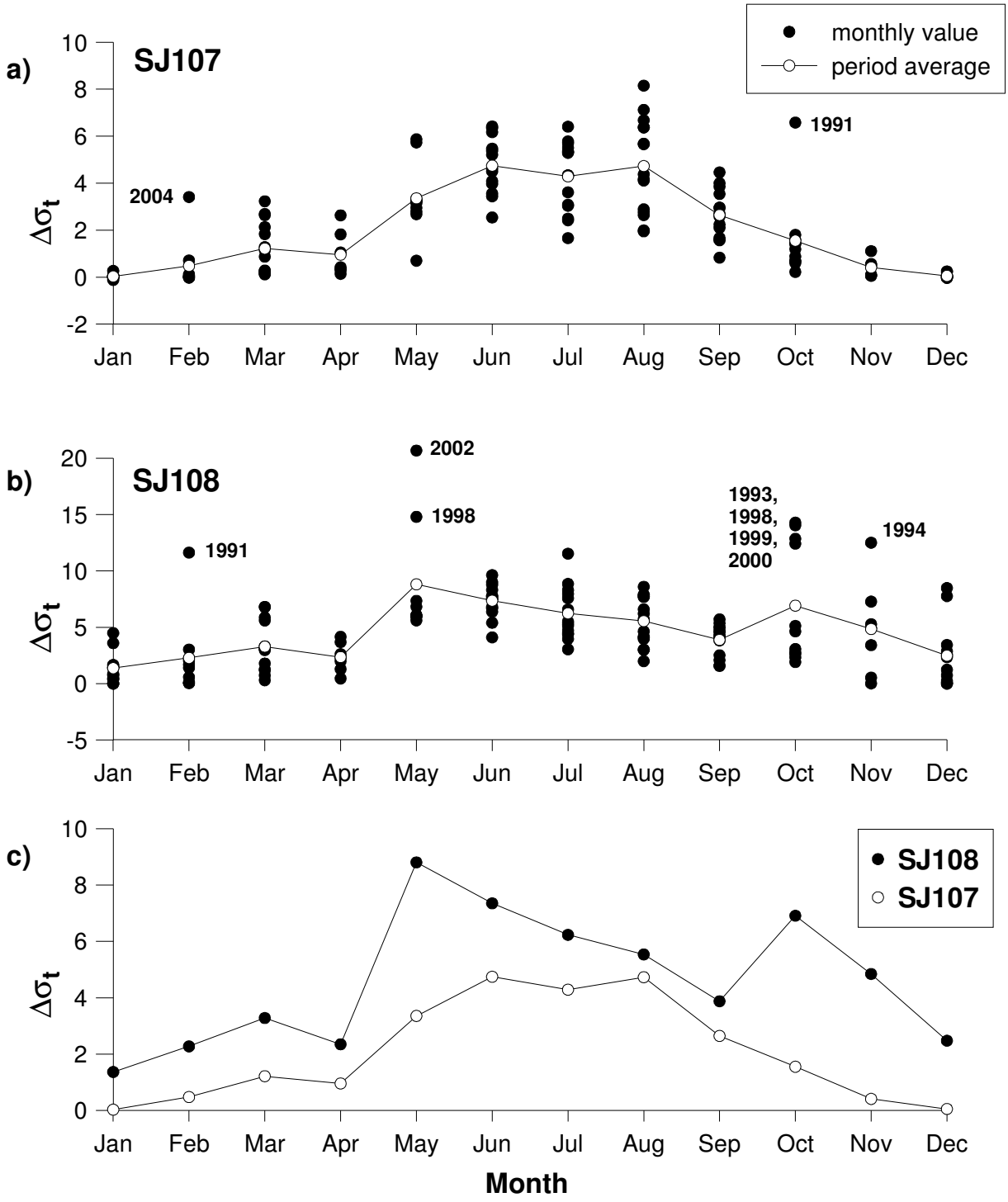
- Suppl.2. (figure)

- Figure 7. (new version)

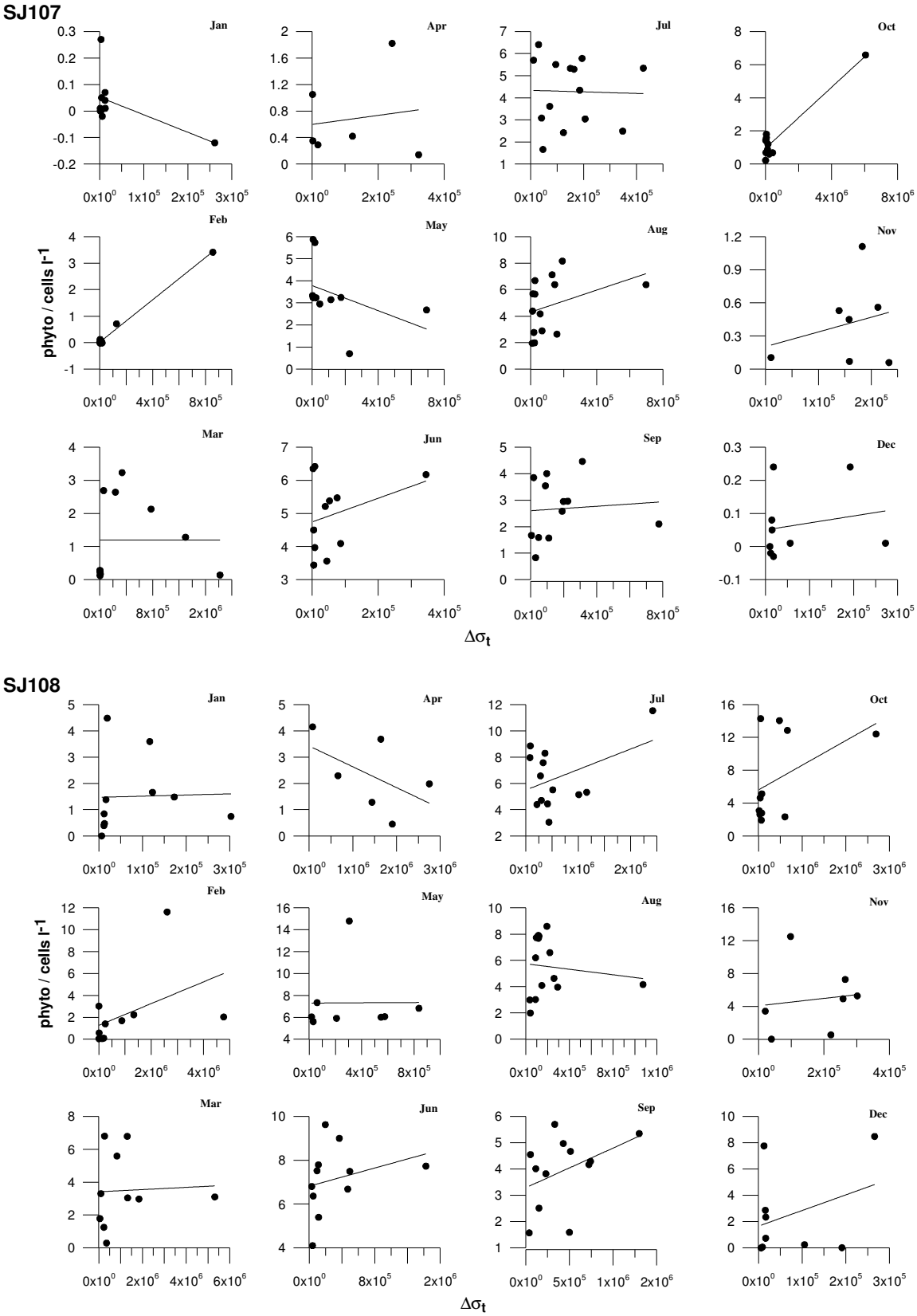
- Figure 10. (new version)

Table 3. Frequency (FREQ) and intensity (INT) of winds from various directions (N, NE, E, SE, S, SW, W. NW) in month of November in years with high (grey background colour) and low evaporation rates (without background colour). Total indicates monthly wind average.

	1993		1998		1999		2001		2003		2004	
	FREQ	INT	FREQ	INT	FREQ	INT	FREQ	INT	FREQ	INT	FREQ	INT
N	8	2.7	2	4.6	3	2.3	2	0.8	1	2.6	2	2.5
NE	43	4.2	38	8.2	38	6.5	45	6.5	29	5.1	24	8.0
E	23	3.6	16	3.6	21	4.8	15	2.9	19	5.0	23	4.6
SE	1	3.4	10	3.0	13	2.6	5	1.7	13	5.6	10	4.1
S	3	1.3	3	4.4	-	-	-	-	-	-	-	-
SW	2	1.6	8	9.4	4	5.5	12	4.8	3	2.5	9	5.0
W	3	2.2	2	4.3	4	3.4	2	1.7	5	1.9	7	1.9
NW	1	3.4	8	4.8	6	3.7	8	3.1	13	2.7	8	1.8
Total	-	3.4	-	6.1	-	5.0	-	4.8	-	4.1	-	4.7



Suppl. 1. Monthly distribution of stratification degree (σ_t at surface - σ_t at bottom) measured during the 1990-2004 period at: a) SJ107 (in the eastern part of the Po River – Rovinj profile), b) SJ108 (in the western part) and c) comparison of monthly averages of stratification degree at SJ107 and SJ108. Values at a) and b) presented in black, averages in white circles.



Suppl. 2. Phytoplankton abundance (phyto; cells l^{-1}) and stratification degree ($\Delta\sigma_t$; σ_t at surface - σ_t at bottom) measured during the 1990-2004 period presented for each month at: a) SJ107 (in the eastern part of the Po River – Rovinj profile) and b) SJ108 (in the western part).

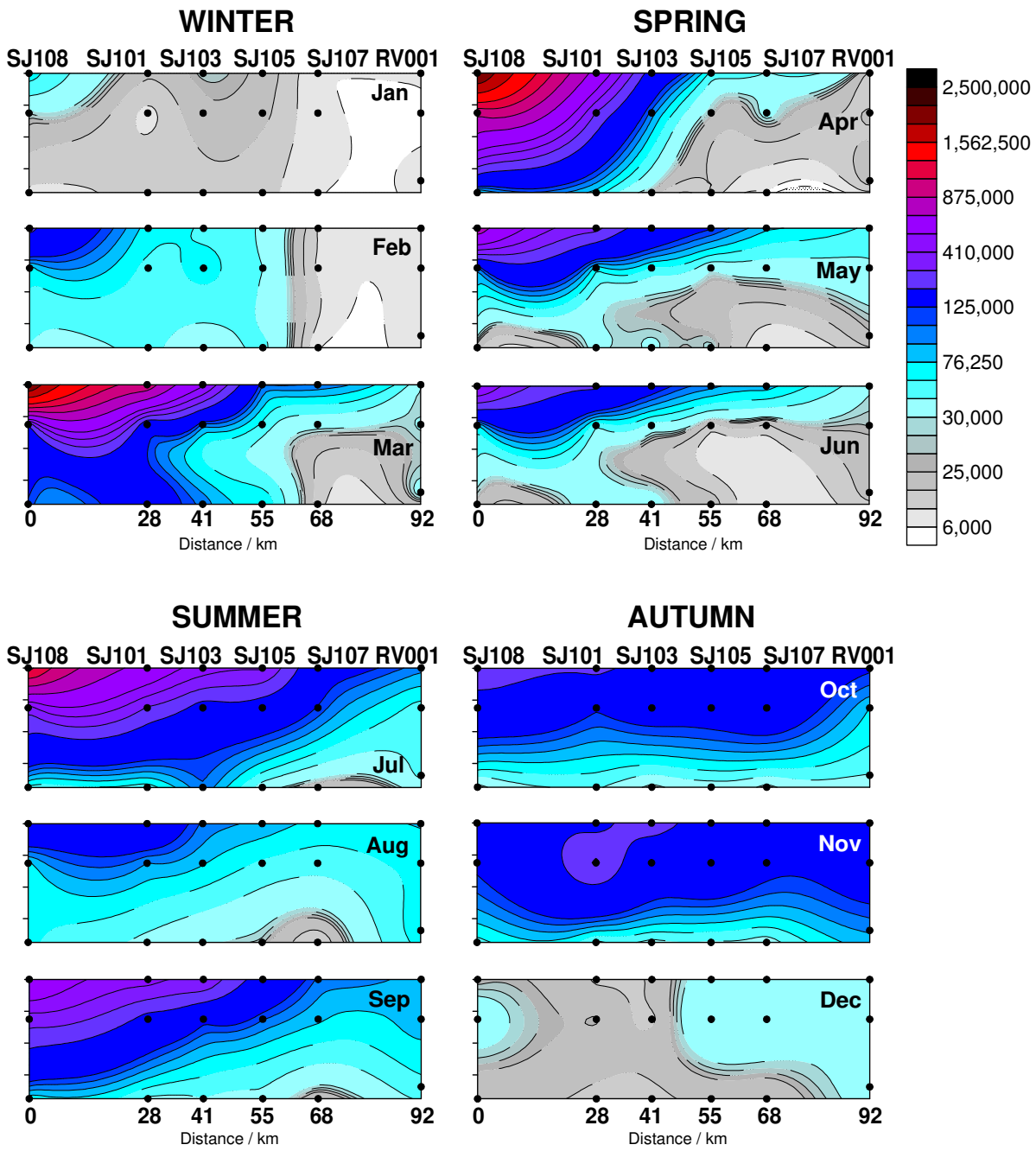


Figure 7

Figure 7. Geometrical means for each month of the phytoplankton abundance in the 1990-2004 interval.

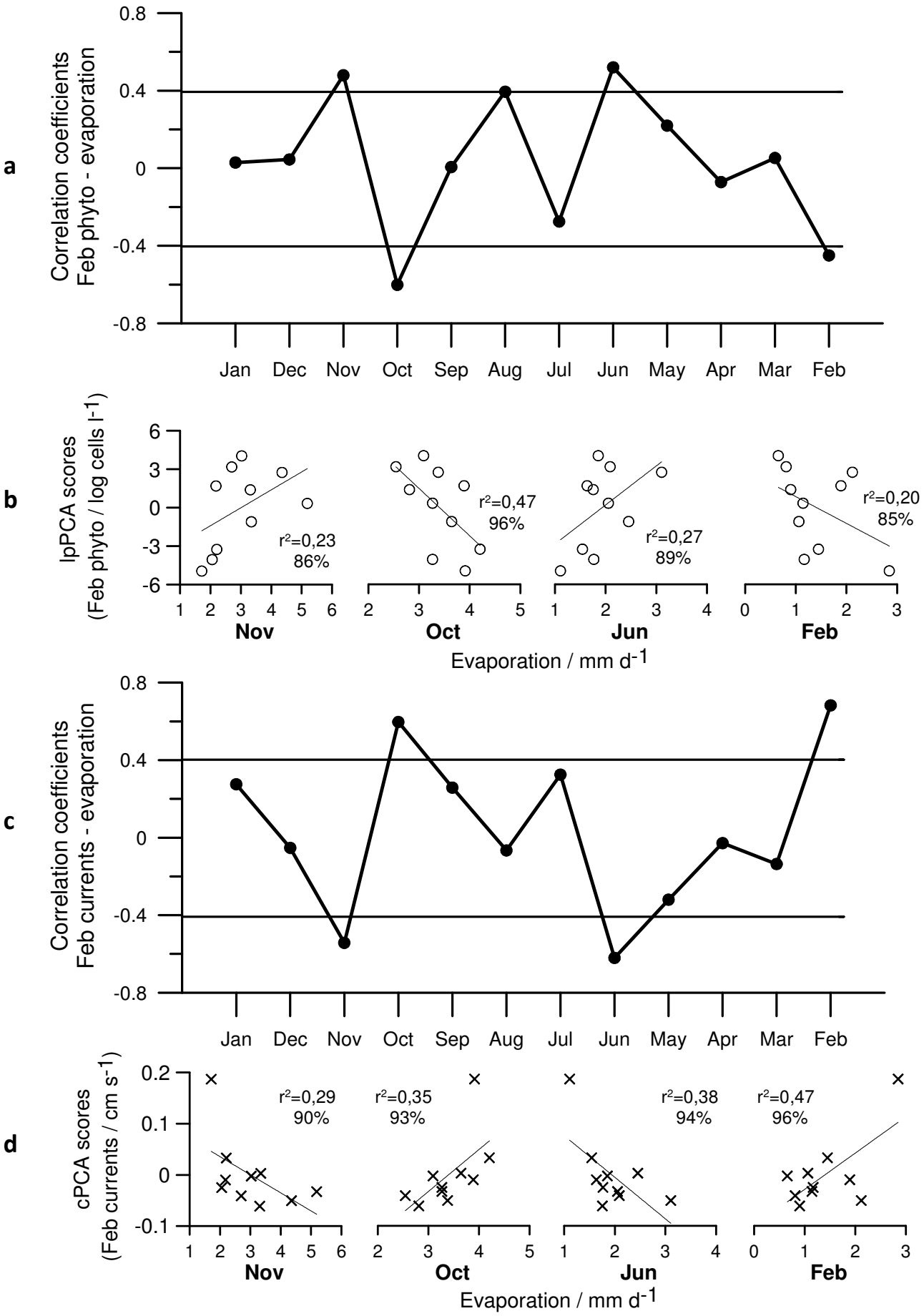

a
Correlation coefficients
Feb phyto - evaporation
0.8
0.4
0
-0.4
-0.8
Jan Dec Nov Oct Sep Aug Jul Jun May Apr Mar Feb
b
lpPCA scores
(Feb phyto / log cells l-1)
r²=0,23
86%
r²=0,47
96%
r²=0,27
89%
r²=0,20
85%
Nov
Oct
Jun
Feb
Evaporation / mm d-1
c
Correlation coefficients
Feb currents - evaporation
Jan Dec Nov Oct Sep Aug Jul Jun May Apr Mar Feb
d
cPCA scores
(Feb currents / cm s-1)
r²=0,29
90%
r²=0,35
93%
r²=0,38
94%
r²=0,47
96%
Nov
Oct
Jun
Feb
Evaporation / mm d-1

Figure 10

Figure 10. Correlation coefficients and lpPCA scores of February (log values of phytoplankton; a and b) and cPCA (geostrophic currents; c and d) against monthly averages of evaporation of the previous year during the analysed period (1989-2004) at the Po River delta-Rovinj profile (a and c). Correlations in November, October, June and February are given graphically (b and d). (We point out that after removal of 2004 data, which were of extreme values, the November correlation slightly decreases, October correlation strengthens while June and February correlations significantly reduce. However, in extreme situations relations between processes become more pronounced and thus should not be removed in computation of correlations, as was discussed earlier by Kraus and Supić, 2011.)