ONLINE SUPPORTING MATERIAL

for the paper bg-2012-178: **"Simulating the effects of phosphorus limitation in the Mississippi and Atchafalaya River plumes"** by A. Laurent, K. Fennel, J. Hu and R. Hetland.

1 Patterns of nutrient limitation with the EPA and LUMCON data sets

In addition to Fig. 7, we provide here a comparison of simulated nutrient limitation factors with the observations from the EPA (Lehrter et al., 2009, 2012, Fig. S1) and LUMCON (Rabalais et al., 1999, 2007, Fig. S2) data sets.

2 N+P co-limitation

We present in the following a description of nutrient limitation patterns when the nutrient limitation factors include N+P co-limitation. The model simulates phytoplankton growth that is limited by either N or P but not both (Eq. 4). However, we can assume that N+P co-limitation occurs when the limitation factors L_{N} and L_{P} are similar. This situation is encountered in nutrient addition bioassays where a sample is considered co-limited when phytoplankton concentration increases with a simultaneous addition of N and P but does not when either is added separately. This should occur only if L_{N} and L_{P} are similar in size. Therefore, we redefine the nutrient limitation factors to include N+P limitation as follows:

1) N limited: if $L_{\mathrm{N}} < (L_{\mathrm{P}} - 0.1)$ and $L_{\mathrm{N}} < 0.75$

2) P limited: if $L_{\mathrm{P}} < (L_{\mathrm{N}} - 0.1)$ and $L_{\mathrm{P}} < 0.75$

3) N+P limited: if $|L_{\mathrm{N}} - L_{\mathrm{P}}| < 0.1$ and $L_{\mathrm{N}} < 0.75$ and $L_{\mathrm{P}} < 0.75$

4) otherwise, phytoplankton growth is not nutrient limited.

The spatial patterns of nutrient limitation simulated during the eight cruises described in Sylvan et al. (2006, 2007, 2011) and Quigg et al. (2011) are presented in Fig. S3. The seasonal evolution of nutrient limitation shows that N+P co-limitation seldom occurs during 2001 (Fig. S3a–d). In March, when nutrient loading is high and nutrient limitation is found in the deeper shelf areas, weak N+P co-limitation occurs only at the edge of the Mississippi river plume (Fig. S3a). N+P co-limitation seldom occurs in May (Fig. S3b) and July (Fig. S3c) when P limitation develops on the Louisiana Shelf and in September (Fig. S3d) when the entire shelf is N-limited. Similar patterns are found in 2002 (Fig. S3h) and 2004 (Fig. S3e–g) with only weak N+P co-limitation at the edge of the Mississippi river plume in March. The simulated patterns of N+P co-limitation agree well with observations (Fig. S3a-h) with notable discrepancies only in July 2002 and 2004 near Terrebonne Bay, where N+P co-limitation is observed but P limitation is simulated (Fig. S3g, h). The same mismatch occurred in this area when using only the N and P limitation factors.

The seasonal cycle of spatially-averaged nutrient limitation factors shows that N+P co-limitation is not an important source of limitation to phytoplankton growth during the entire period of simulation. Weak N+P co-limitation occurs only on a few occasions in the Far-field region. Overall, the spatial and temporal patterns of N and P limitation remain the same as when using only the N and P limitation factors.

The spatial extent of N+P co-limitation is not very sensitive to changes in the $\mathrm{N:P}$ ratio of the river nutrient load (Fig. S5c). The only difference between the P load treatments occurs in September when the area of N+P co-limitation increases with a decrease in river phosphate. However, the total N+P-limited area is rather small ($< 0.5 \times 10^4\,\mathrm{km}^2$ on average) in comparison to the P- and N-limited areas.

Overall, consideration of N+P co-limitation does not change the analysis of nutrient limitation.

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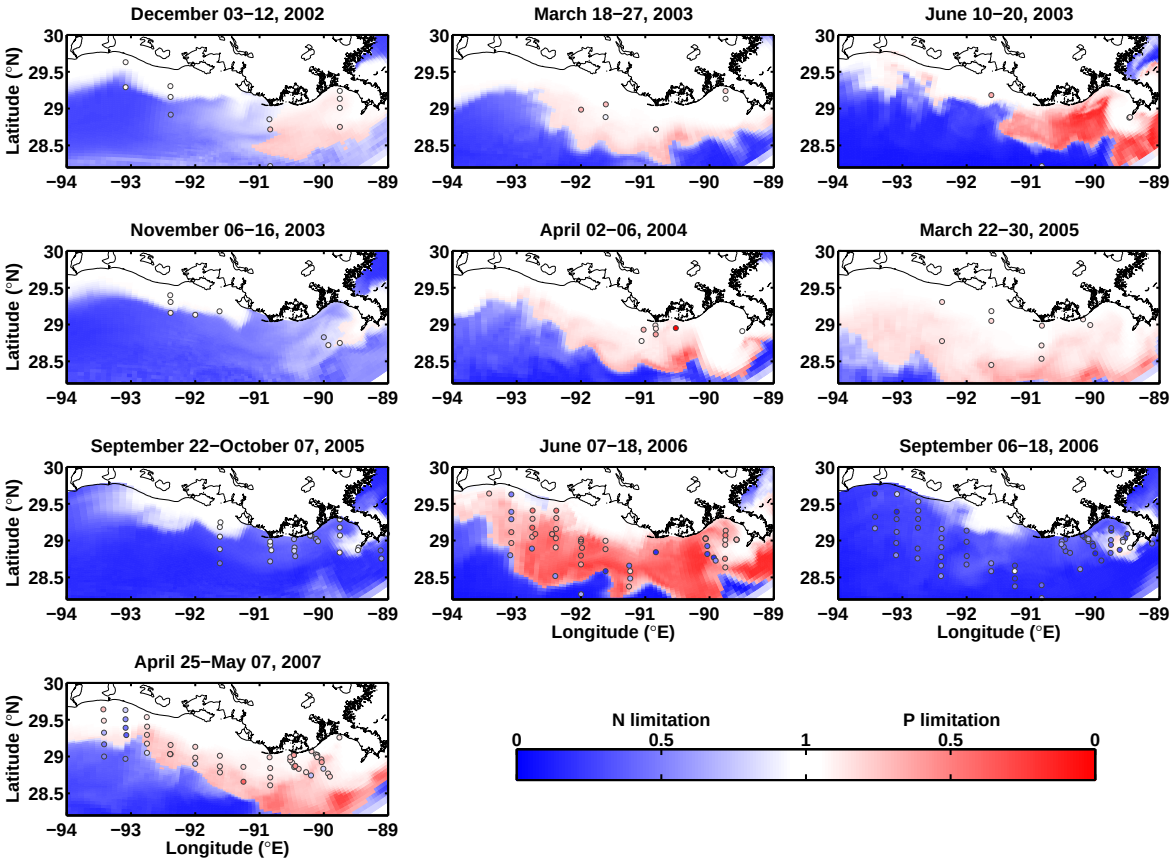

Fig. S1. Simulated (colour maps) and observed (circles) nutrient limitation factors during the EPA shelf cruises. The colour-coded scale represents N limitation (blue), P limitation (red) and no nutrient limitation (white).

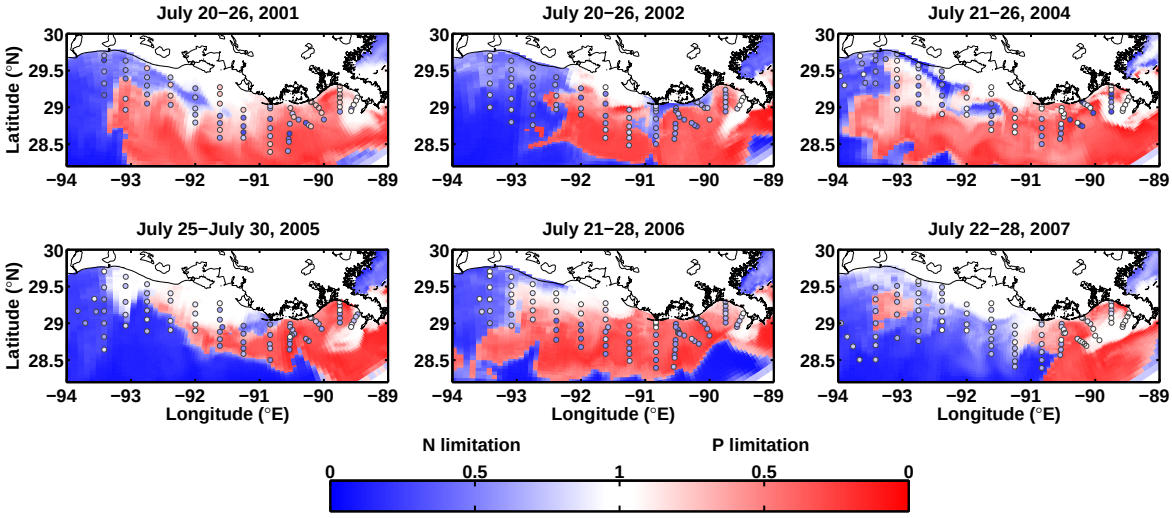

Fig. S2. Simulated (colour maps) and observed (circles) nutrient limitation factors during the LUMCON hypoxia cruises. The colour-coded scale represents N limitation (blue), P limitation (red) and no nutrient limitation (white).

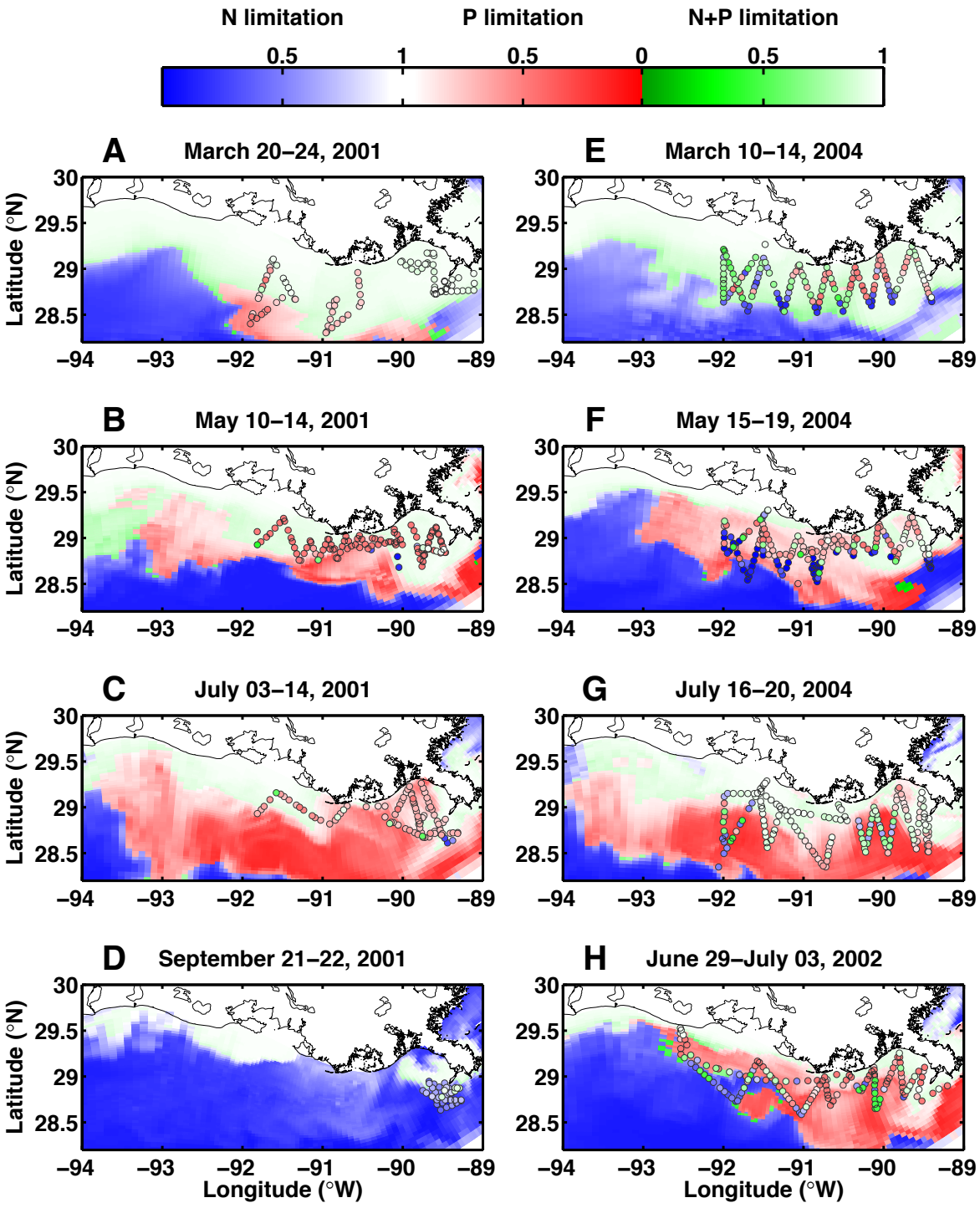

Fig. S3. Simulated (colour maps) and observed (circles) nutrient limitation on the Louisiana shelf in March, May, July and September 2001 **(A–D)**, in March, May and July 2004 **(E–G)** and in June-July 2002 **(H)**. The colour-coded scale represents N limitation (blue), P limitation (red) and N+P limitation (green), whereas there is no nutrient limitation in the white regions.

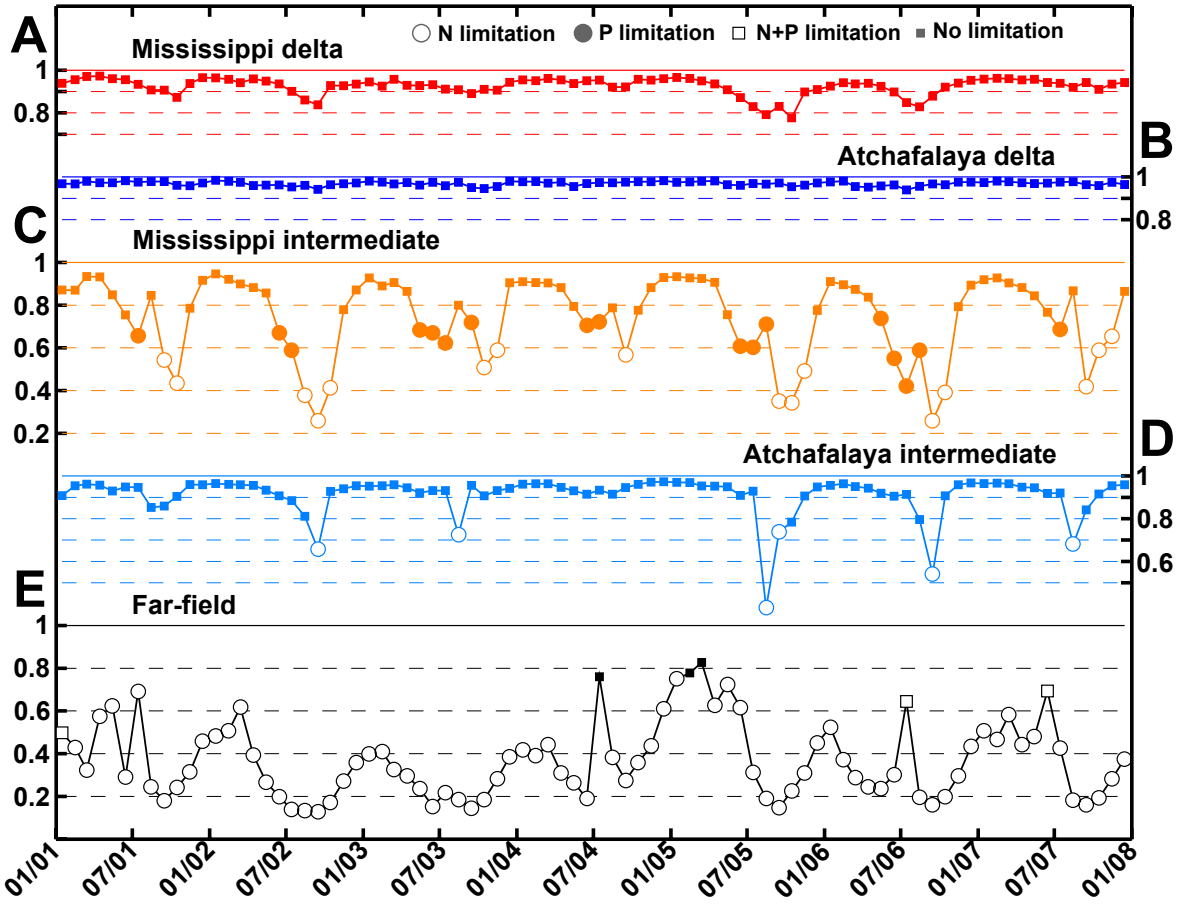

Fig. S4. Times series of monthly mean, area-averaged type and magnitude of N (open circles), P (closed circles) limitation and N+P (open squares) co-limitation factors for the five regions described in Fig. 1. Closed squares indicate the absence of nutrient limitation.

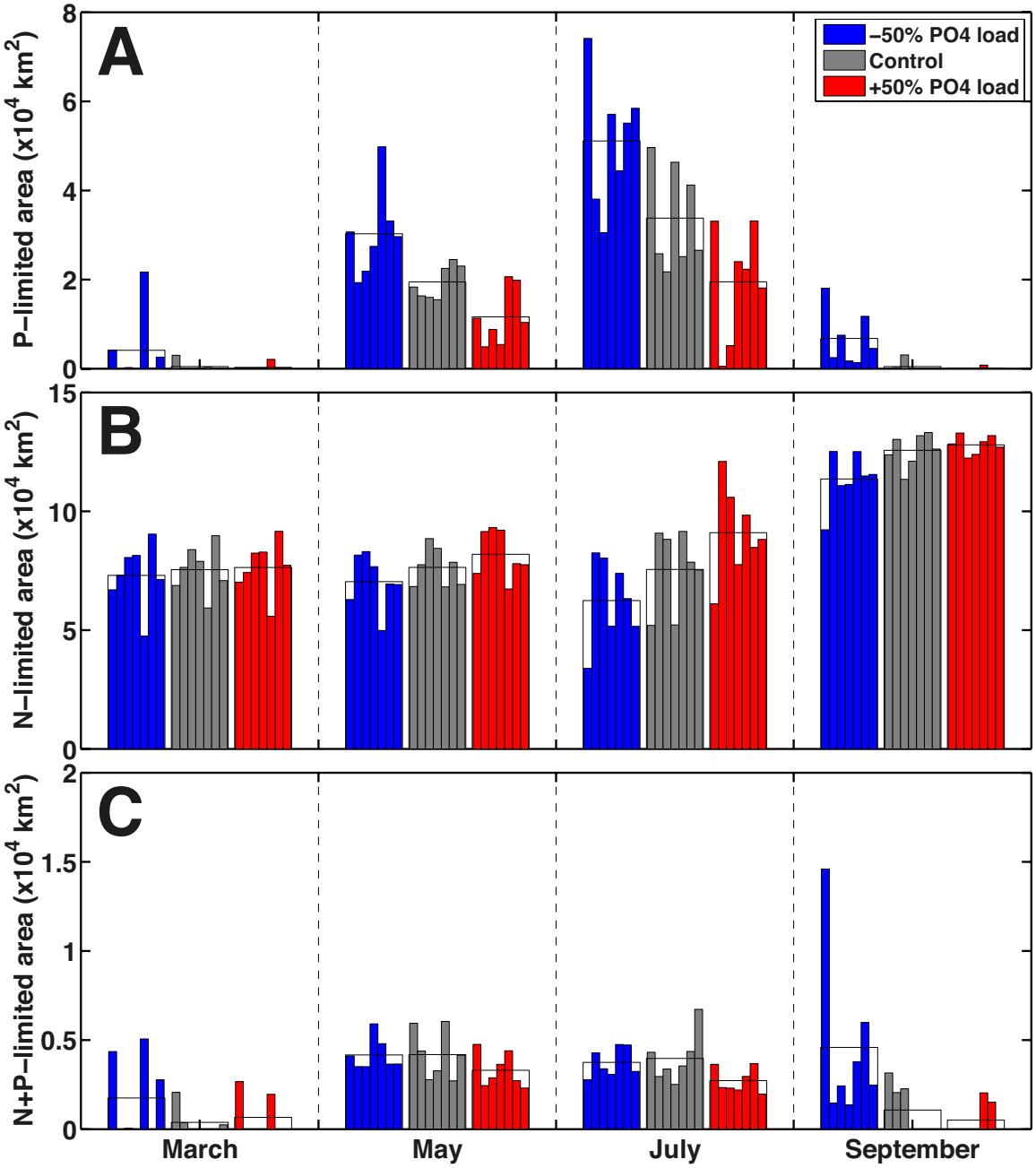

Fig. S5. Total area of surface P **(A)**, N **(B)** and N+P **(C)** limitation ($L < 0.75$) in March, May, July and September for the control simulation (grey) and for the model experiments with increased (red) and decreased (blue) river phosphate. Filled bars indicate the monthly average for each year (from left to right, 2001–2007) and open bars indicate the average calculated over the whole simulation. Total model area is $14.6 \times 10^4\,\mathrm{km}^2$.