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North Atlantic Report #64:
Maltrud's Simulation with 3 Phytoplankton Groups

1. Reanalysis of Eddy-Phytoplankton Species Relationships

It was investigated why, in Report #63, Small Phytoplankton (SP) are high in anticyclones (AC) and low in cyclones (C). Fig. 1a shows model output for 31.7°N, 35-75°W for summer (days 150-300 from years 1 and 2). Low potential density at 70 m is dominated by regular anticyclones that occur near 68°W in late summer in both years. The two eddies in the second year are high in SP (and DIAZ). The movie

http://www.whoi.edu/science/AOPE/people/landerson/NATL/vort_phytolog.avi

shows that these anticyclones originate from the anticyclonic water on the south side of the Gulf Stream. When a cyclonic cold core ring forms, it appears to peel off a corresponding anticyclone as well. This water just south of the Gulf Stream is particularly high in DIAZ and SP in late summer. Fig. 1b shows that if the 65-75°W band is excluded from the analysis (as being related to Gulf Stream rings rather than interior eddies), high SP then correlates with C instead of AC.

Restricting the domain to 35-65°W (Fig. 2) shows Total Chl (and DIAT) correlated with C and MWE, and SP with C, but now DIAZ are no longer correlated with AC (as in Report #63). This disagrees with the observations of Davis and McGillicuddy (2006), though the analysis in Fig. 2 is not exactly the same as in Davis and McGillicuddy (2006). In Fig. 2 (and Report #63), the model output was detrended by removing the climatological temporal trend, which was computed as a temporal OA of both years' model output combined, using a 30-day e-folding scale. This is done at each longitude independently, which effectively removes the large-scale spatial gradient. In Davis and McGillicuddy (2006), instead the data is detrended by removing the large-scale spatial trend. So in Fig. 3, the model anomalies are computed by removing the large-scale spatial trend for each 5-day average, estimated by an zonal OA with a 300-km (viz. 30 grid point) e-folding scale. In Fig. 3 DIAZ are correlated with positive SLA (AC and MWE), though not with high T as in Davis and McGillicuddy (2006).

The difference between the Figs. 2a and 3a reveal significant sensitivity of the conclusions to how the background (spatial or temporal) trend is estimated. Which is better to use? Fig. 4a shows the climatological temporal trends (computed using a 30-day e-folding scale from all years combined, as is typically done for BATS time-series data); Fig. 4b shows the resulting anomalies i.e. Fig. 1a minus Fig. 4a. It can be seen that in some locations "false" anomalies occur, due to an eddy being present in one year but not the other. (This is a significant problem because we have only two years of output; however interannual variability in a time series would cause a similar problem.) Thus this method can lead to spurious conclusions. Fig. 5a shows an estimate of the temporal trend with each year treated independently (again using a 30-day e-scale). The estimated anomalies (Fig. 5b) however lack most of the eddy signal (compare Fig. 5b with Fig. 1a), due to the e-scale being too short, while at the same time some spurious anomalies are introduced, due to the e-scale being too long. Thus this is not a good method either. Part of the problem is the similarity in timescale of eddies and the winter-spring transition. Fig. 6a shows the large-scale spatial trend (using a 300-km e-scale). While it does contain some of the eddy signal, the resulting anomalies (Fig. 6b) appear to be a good representation of the eddy field (compare with Fig. 1a). Note this also removes the seasonality. (It actually removes even higher temporal frequences, but only those corresponding to the 300-km scale or greater, and such variations are not large.) Another alternative would be a trend based on a simultaneous spatiotemporal OA; but as attempting to remove the temporal trend caused difficulties, this was not considered advantageous.

In summary, removing the large-scale spatial trend rather than the temporal trend works better for identifying eddies. Results based on these anomalies, for 35-65°W to exclude Gulf Stream-related eddies found between 65-75°W, are shown in Figs. 7-9. High Total Chl and DIAT are found in MWE and C. High SP are found in C. High DIAZ are found in positive SLA (AC and MWE). The Percent DIAT is highest in C and MWE, while for SP and DIAZ their percentage is highest in AC and TH. PP (Fig. 8a) and Growth rates (Fig. 9a) are enhanced in MWE and C for all species, due to higher nutrients (Fig. 9b). POC flux is highest in MWE and C. S is low in low SLA anomalies, which might be an indication of horizontal advection.

- Do the results now agree with observations? SP is highest in cyclones and lowest in anticyclones. Is that observed? DIAZ are high in AC, but also MWE, though Davis and McGillicuddy (2006) did not sample MWE. Did the EDDIES data find high DIAZ in MWE? Total Chl and DIAT are equally high in both C and MWE. But the observations suggest MWE should be highest, presumably due to the eddy-wind interaction. So the model biology does not appear to be responding to the eddy-wind interaction, which should differentiate MWE from C. In most instances, the primary biological response is to density at 70 m.

- Why is SP biomass more enhanced in C than MWE? Why does DIAZ respond more to SLA than density at 70 m? How do the DIAZ get their PO_4? Need to examine advection terms versus growth, and growth limitation terms to evaulate these. Low S occurs in low SLA presumably due to advection of the large-scale gradient; examine S advection terms to confirm. If so, then perhaps some of the relationships in Figs. 7-9 are due to advection of biological gradients, which is why Chl relationships (Fig. 7a) do not match growth relationships (Fig. 9a).

- With the BATS data, eddy-species relationships can only be determined by removing a climatological temporal trend (after large-timescale interannual variations are removed). So for direct comparison, should this (Fig. 4) method be used, even though it is flawed? Probably no. Is there another way to analyze the BATS data, that does not require removing the temporal trend? Fortunately most of the BATS biological data do not show summer trends, and the BATS time series is long, so this may not be as big a problem for the data as it is for the model. Also compare both with the EDDIES data and Davis and McGillicuddy (2006).

- Compute means based on log(Chl), rejecting points outside 2 std?

- I tried using SSH instead of SLA; it made litte difference. I also tried using a 70-km OA on the anomaly fields, to remove the submesoscale signal; it made litte difference.

2. NO_3 and Phytoplankton: Comparison with Data

Fig. 10 compares POP-BGC model runs with BATS data. The 0.1° run NO_3 does not agree well with BATS data, while the 3° run does. Both runs agree fairly well with observed Total Chl. Both runs overestimate the Diatom percentage, though the 3° run is somewhat better. The 0.1° results at PseudoBATS (20.1°N, 72.7°W; Fig. 11a) are similar to the 0.1° model results at BATS.

- The Lima 3° run was 240 years long; did it use restoring to NO_3 climatology?

3. POC Flux: Comparison with Data

Fig. 11b shows a snapshot of 0.1° run output with separate SP and DIAT blooms. They both cause high POC flux; however the amount of POC flux per unit Chl (i.e. POC flux in units g C/g Chl/day) is actually slightly higher for the SP bloom than the DIAT bloom. Why? Although C/Chl ratios are not taken into account here, both SP and DIAT have a linear loss rate of 0.1/day to POC. Consequently they contribute similarly to POC flux at 150 m. (DIAT might contribute more to the POC flux at 1000 m, due to ballast.)

- If model DIAT concentrations were lower, i.e. similar to observed, they could contribute a greater relative fraction to POC flux. The fact that DIAT are observed to only be a few percent at BATS suggests that they may have a higher export ratio than SP, or are poor competitors for NH_4 (but superior competitors for NO_3).

Fig. 12 shows summer BATS data estimates of POC or PON flux as a function of vertically-integrated Total Chl or Diatom biomass (estimated from HPLC data and the formula of Letelier et al., 1993). When only summer means are removed from the data, little relationship is seen between POC or PON flux from BATS sediment traps and overlying Chl or Diatom concentrations. This may be due to temporal lags. When seasonal trends are removed (viz. a 30-day e-folding scale OA), PON Flux at 150 m shows a slight positive correlation with Total Chl and a slight negative correlation with Diatom biomass, apparently on account of blooms that are primarily non-Diatom.

- So if we calibrate the model to the BATS data, then DIAT would not contribute much to the POC flux; but is this true? If not, then to what data should the DIAT contribution to POC flux be calibrated?

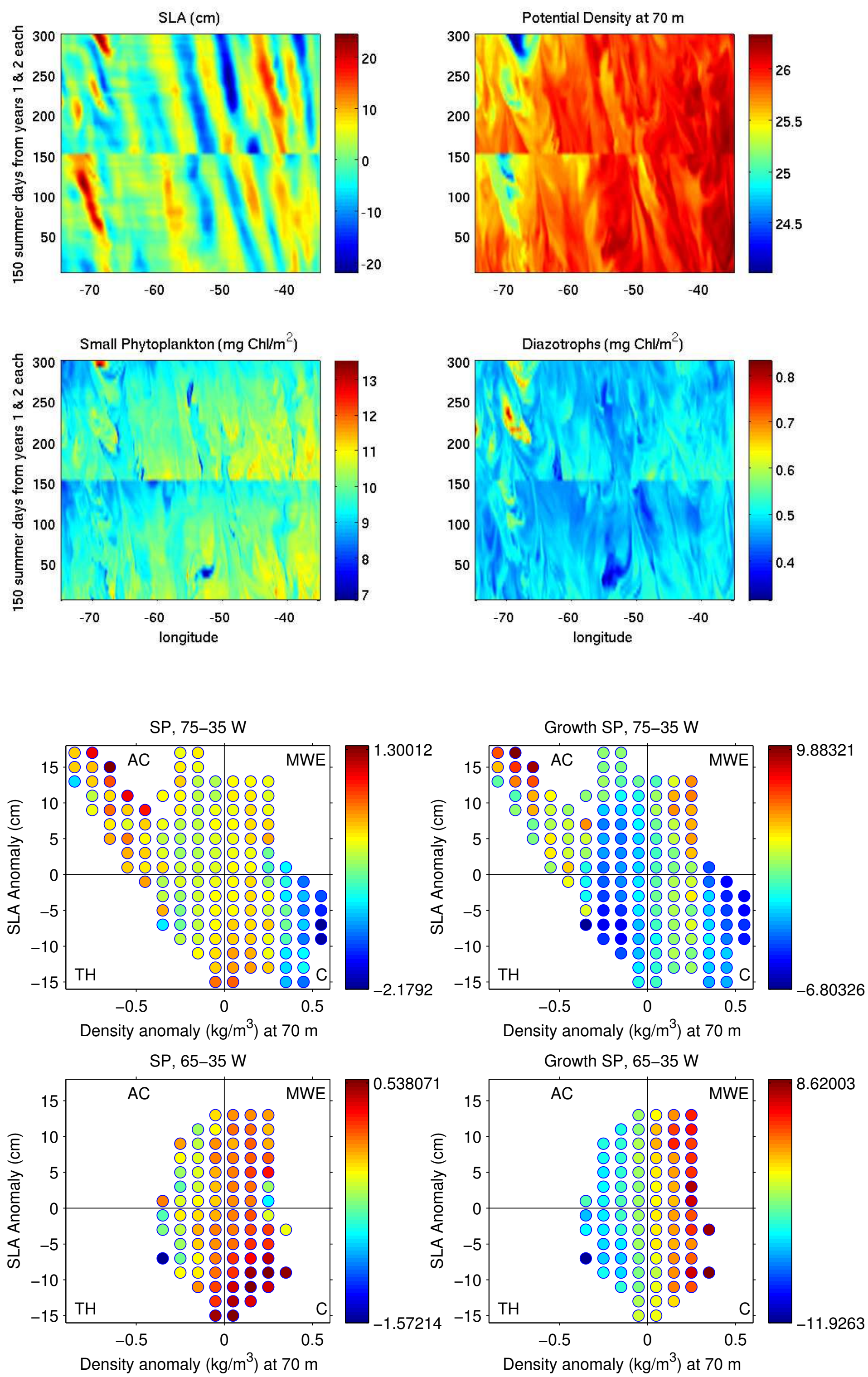

Fig. 1. (a) summer model output at 31.7°N, (b) seasonally detrended anomalies.

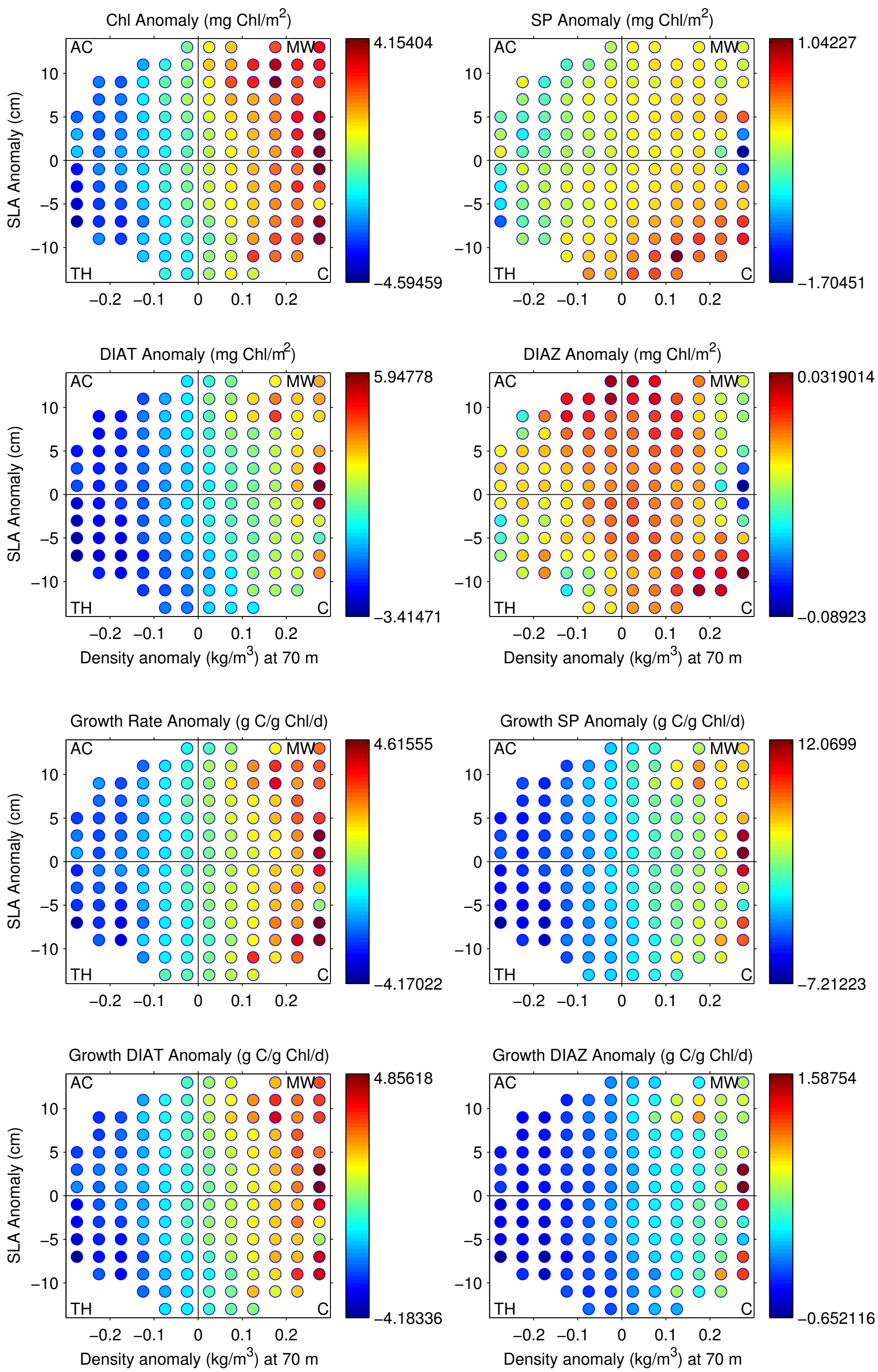

Fig. 2. 0.1° Model, 31.7°N 35-65°W, seasonally detrended anomalies.

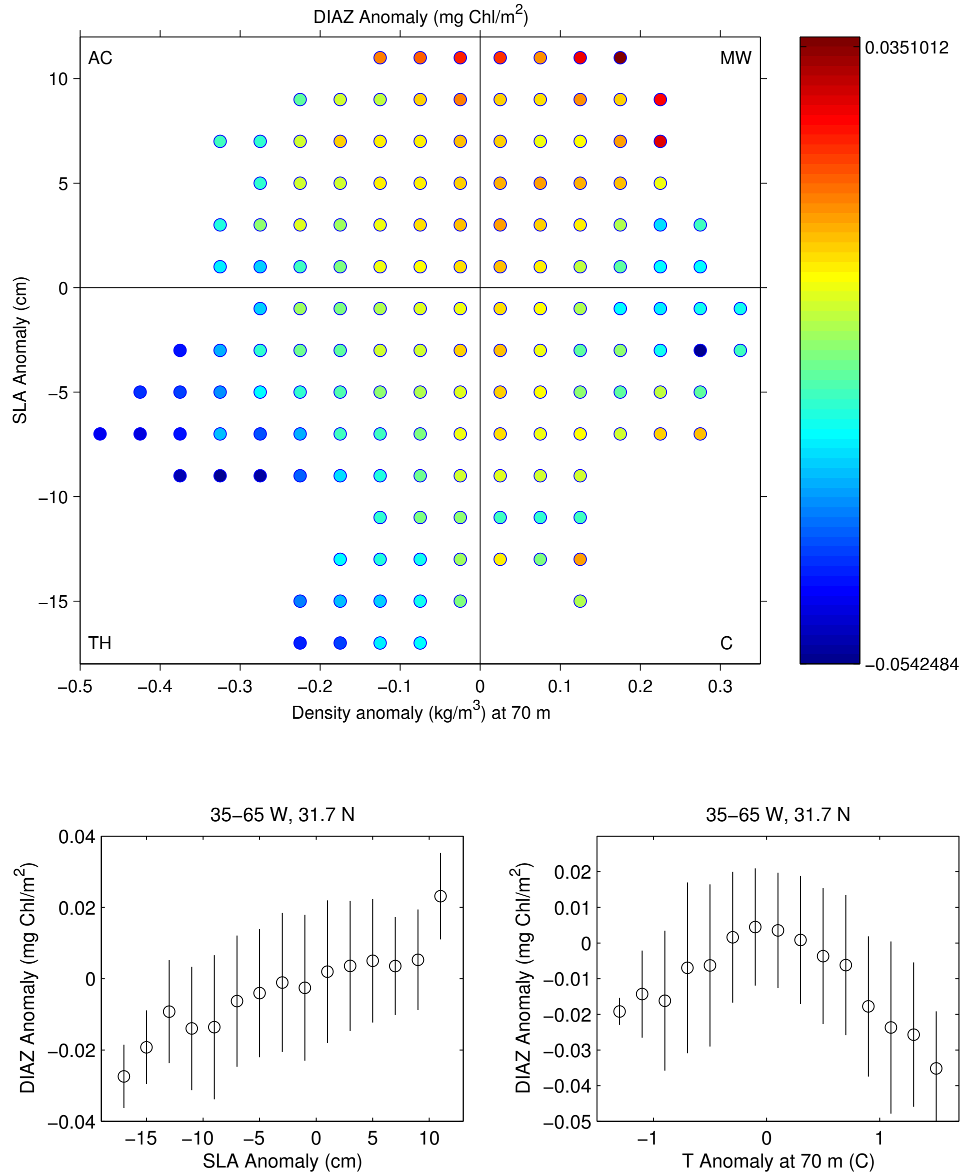

Fig. 3. 0.1° Model, 31.7°N 35-65°W, spatially detrended anomalies.

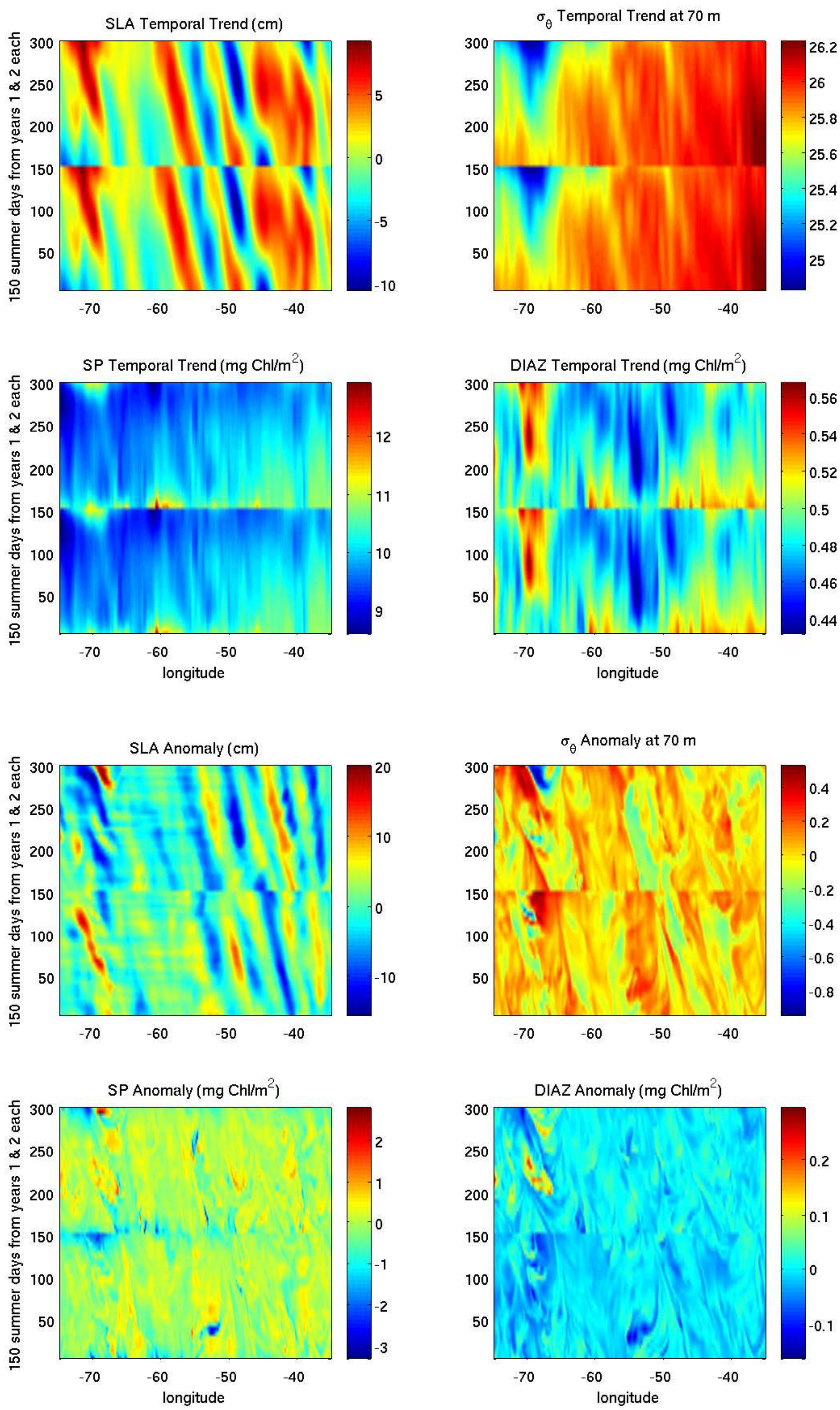

Fig. 4. (a) Climatological seasonal trend, (b) seasonally detrended anomalies.

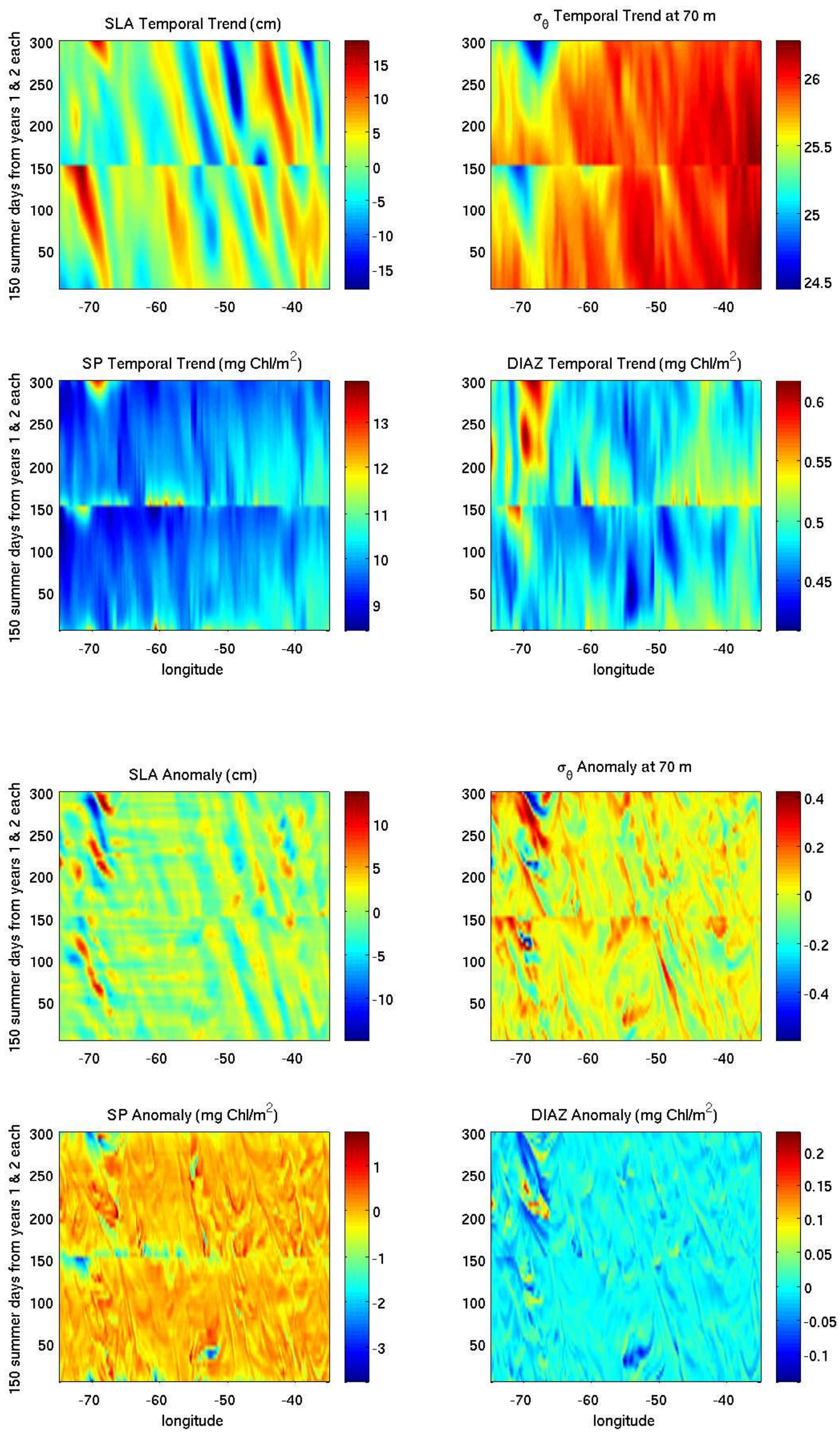

Fig. 5. (a) 30-day temporal trend, (b) temporally detrended anomalies.

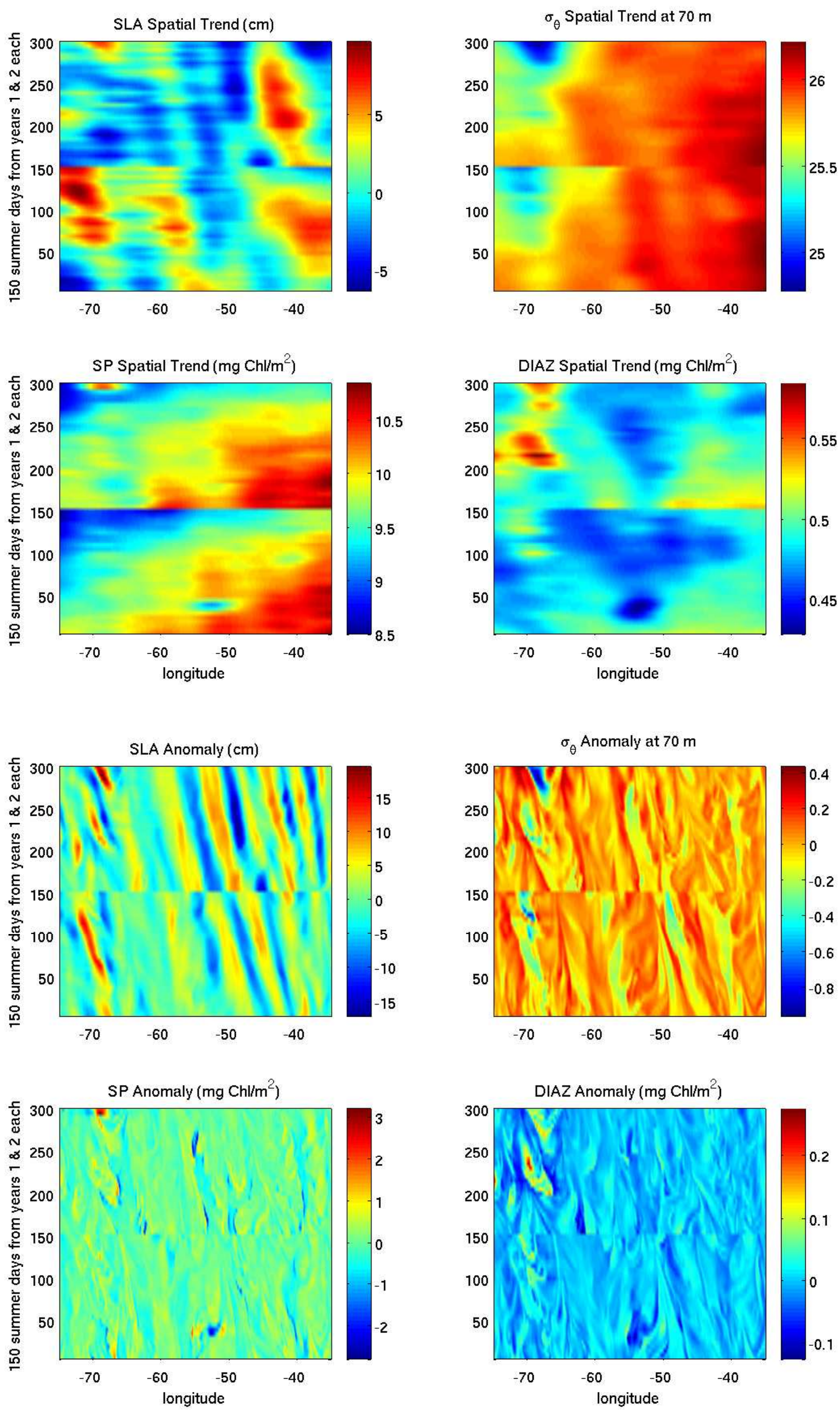

Fig. 6. (a) 300-km spatial trend, (b) spatially detrended anomalies.

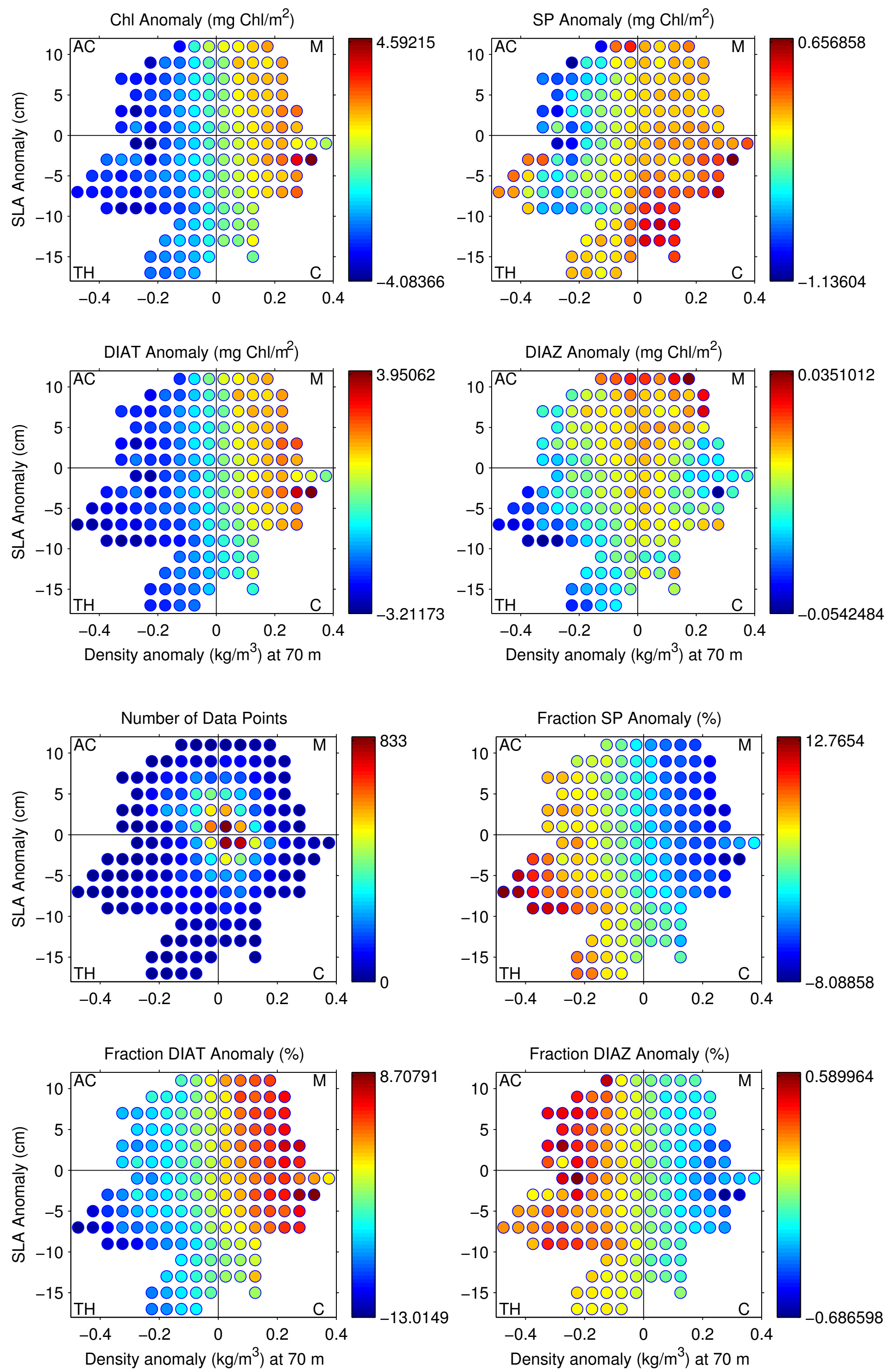

Fig. 7. 0.1° Model, 31.7°N 35-65°W, yeardays 150-300 from 2 years of output.

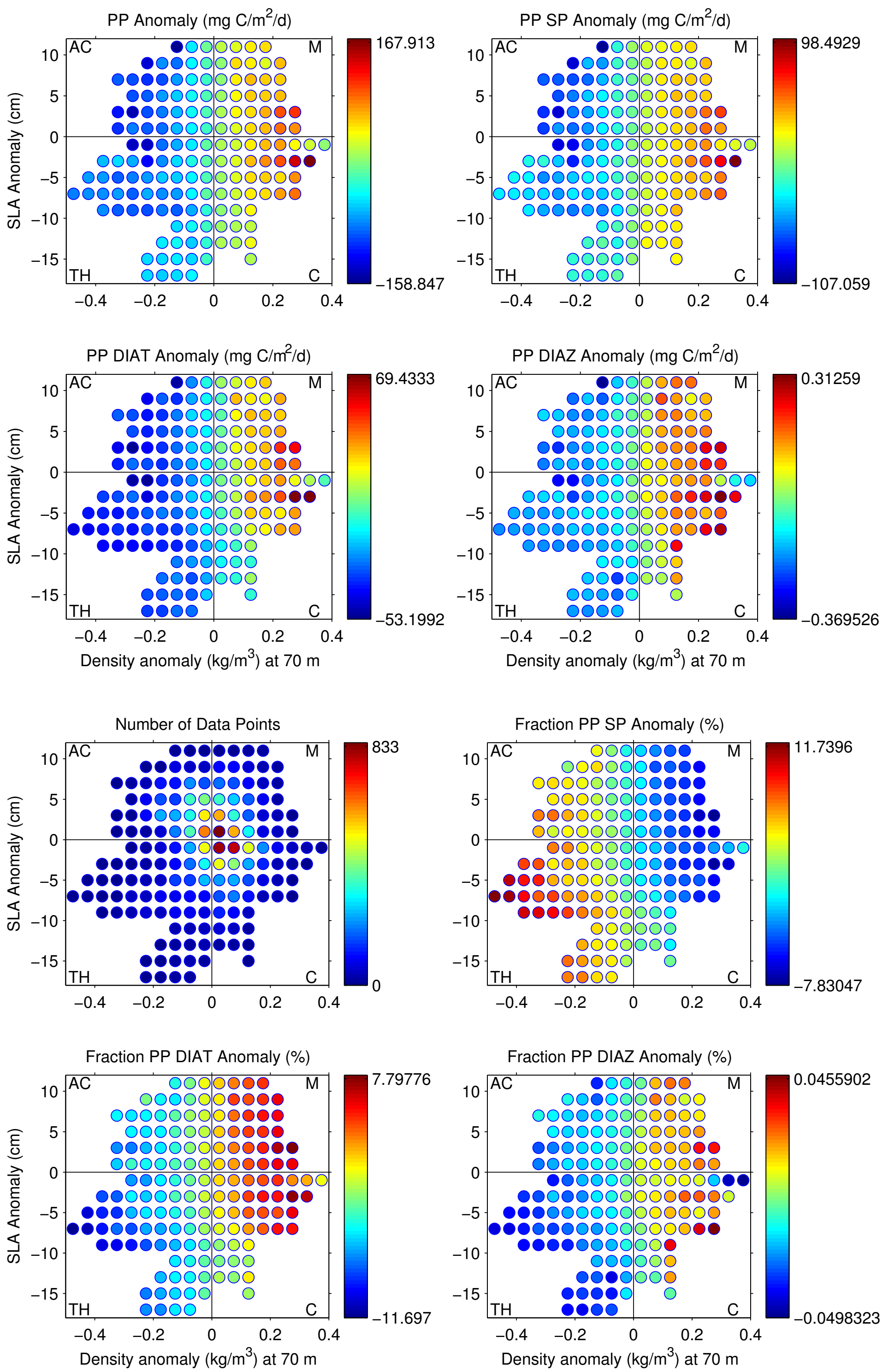

Fig. 8. 0.1° Model, 31.7°N 35-65°W, yeardays 150-300 from 2 years of output.

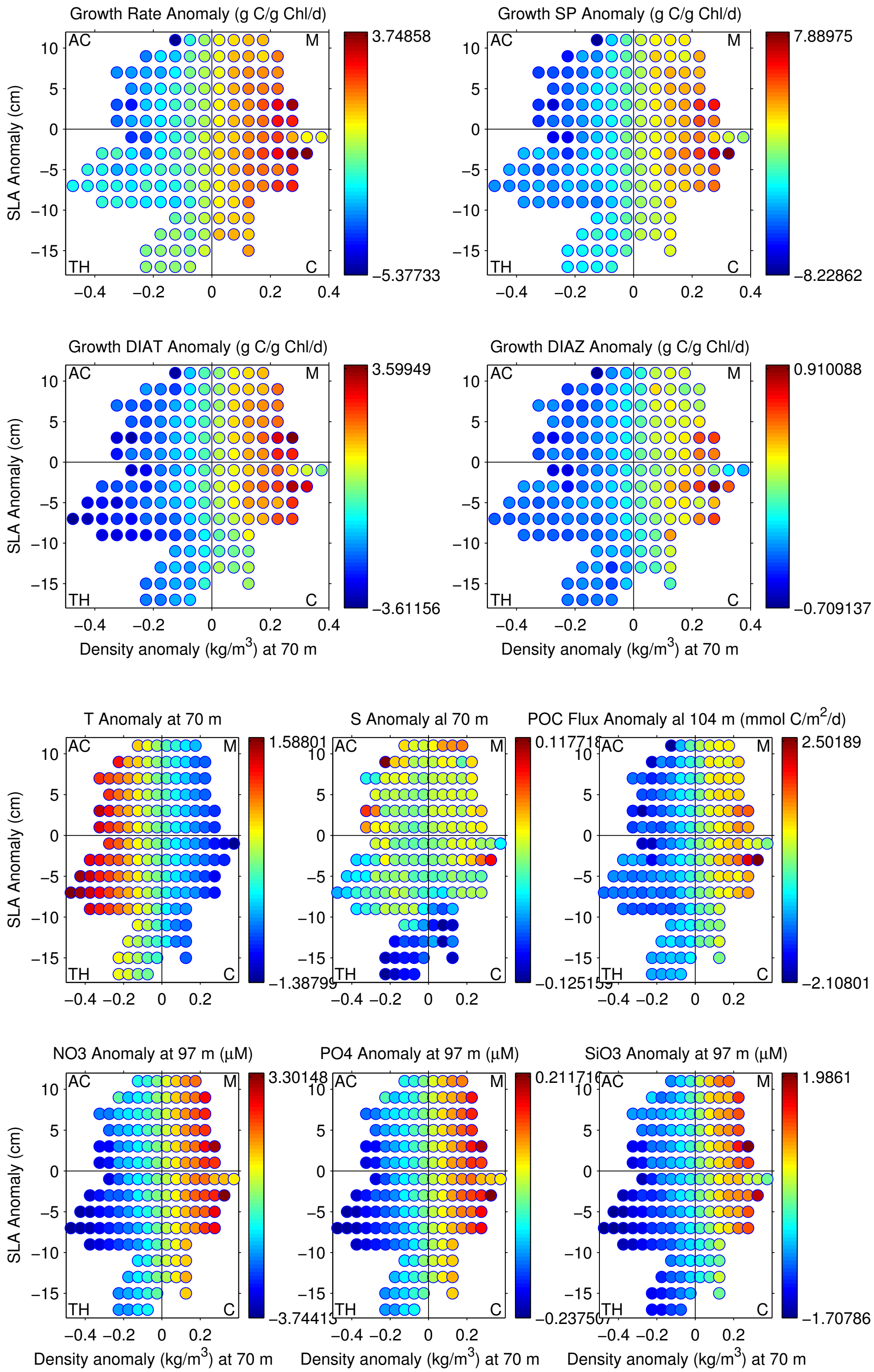

Fig. 9. 0.1° Model, 31.7°N 35-65°W, yeardays 150-300 from 2 years of output.

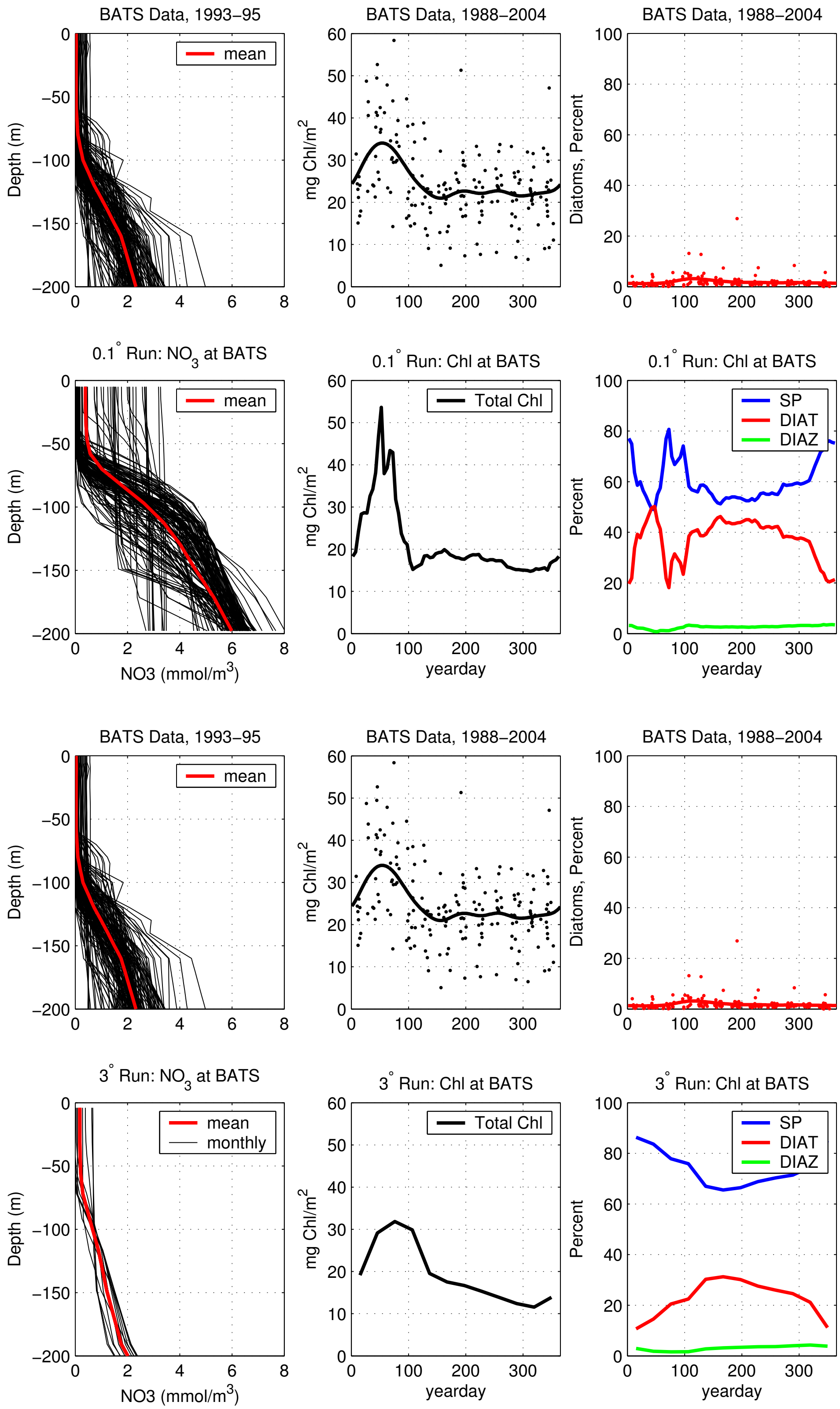

Fig. 10. (a) Comparison of Maltrud 0.1° run with BATS data.
(b) Comparison of Lima 3° run with BATS data.

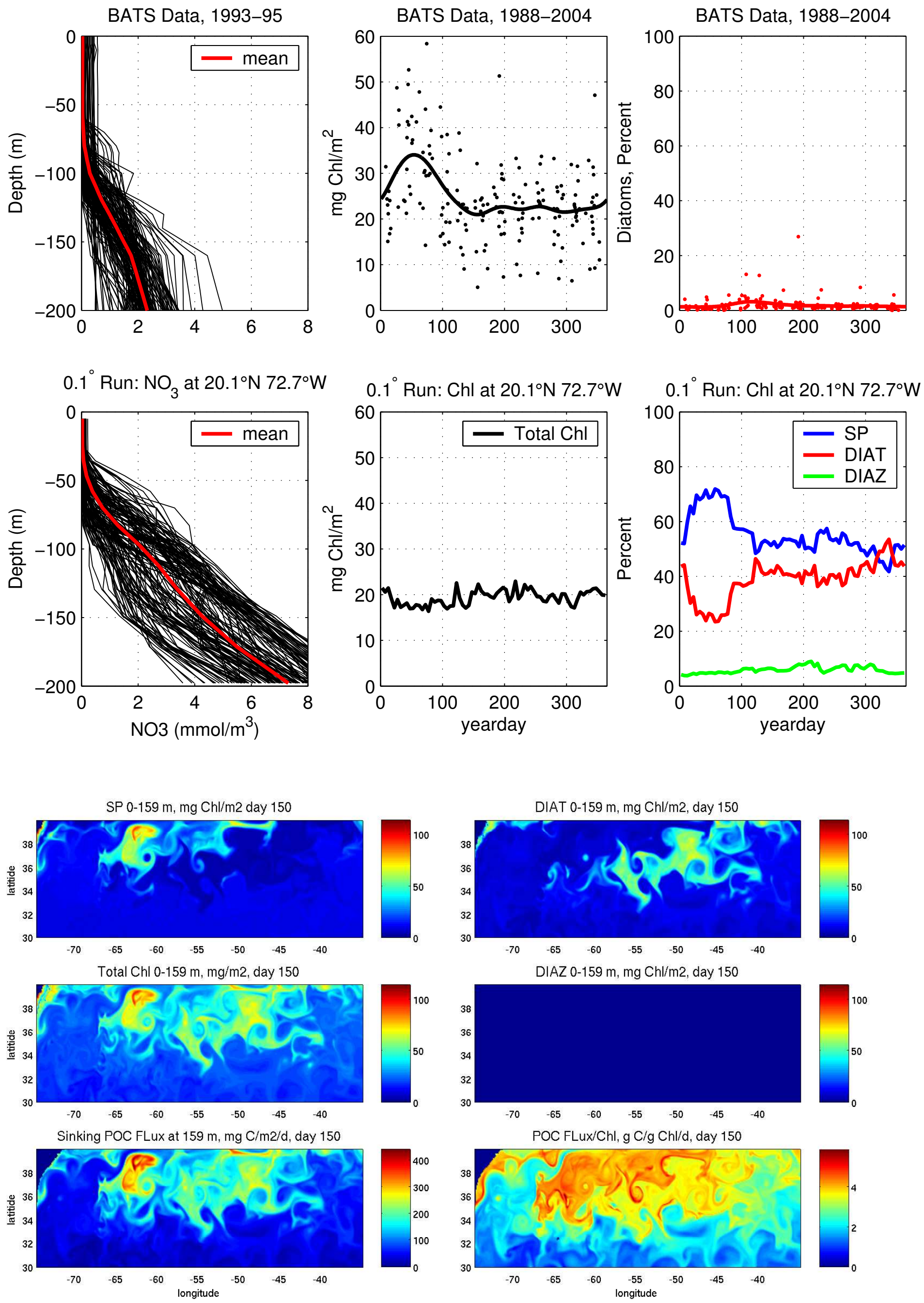

Fig. 11. (a) Comparison of Maltrud 0.1° run at PseudoBATS with BATS data. (b) 0.1° run results on day 150.

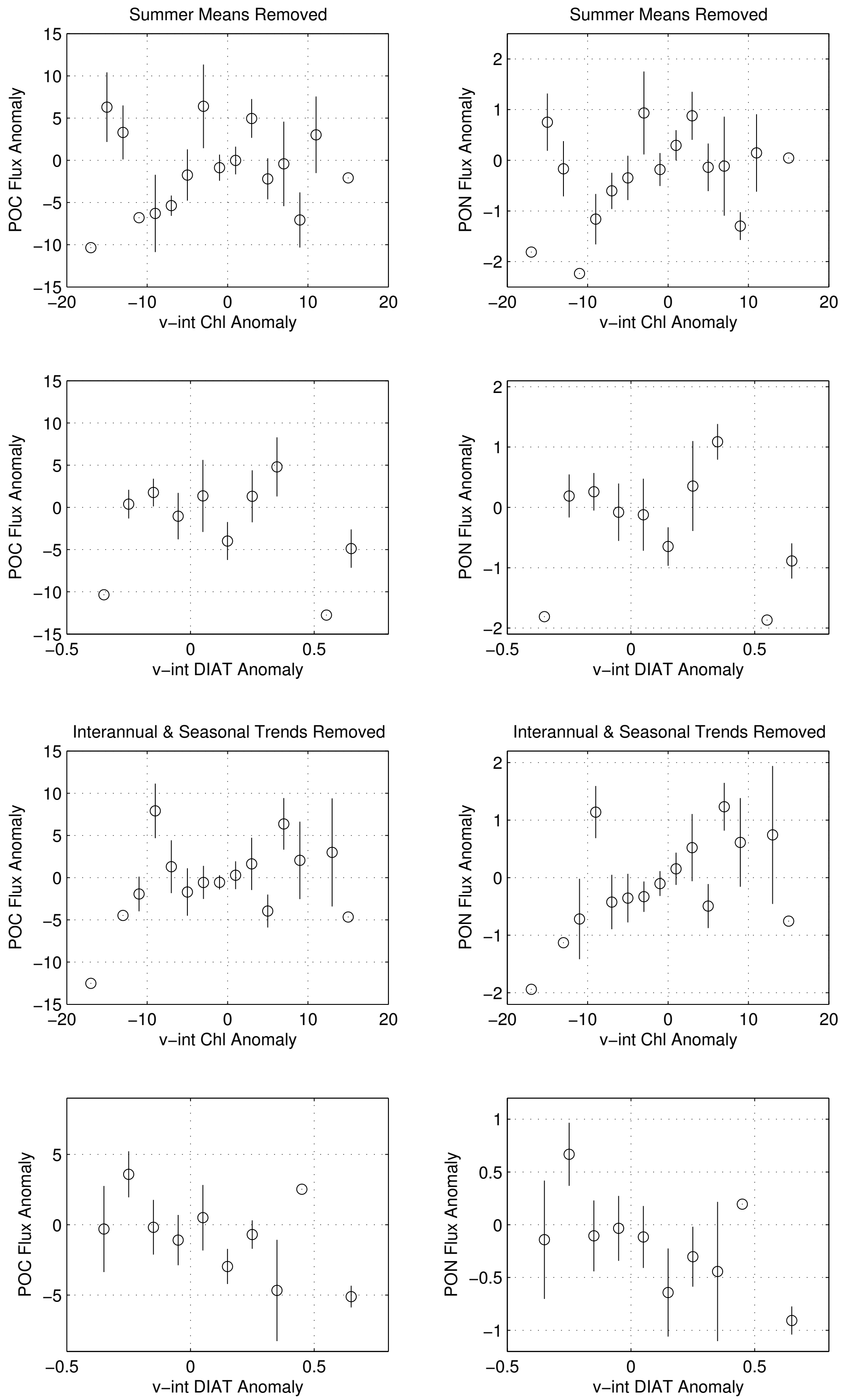

Fig. 12. Summer BATS data relationships.