NENA diagnostics

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NASA IDS meeting

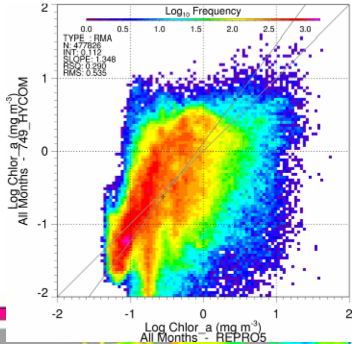
Recap

- Calibrated PAR and k_{PAR} based on SeaWiFS measurements and MARMAP data for the depth of the euphotic zone
- K_{PAR} now compares more favorably with estimates from VGPM2 in the MAB (but not everywhere), but other variables compare less favorably

Some of the following figures are from Jay’s presentation at the last team meeting; the other figures are available at:

http://myweb.dal.ca/kt956023/NENA_801/)

CHLOR_A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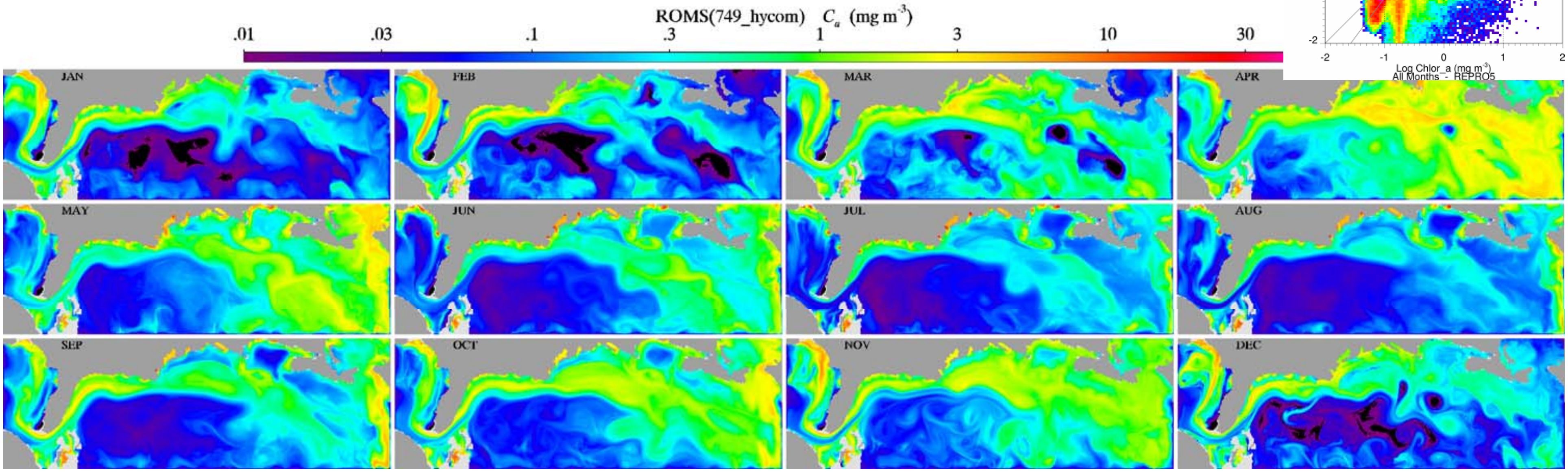
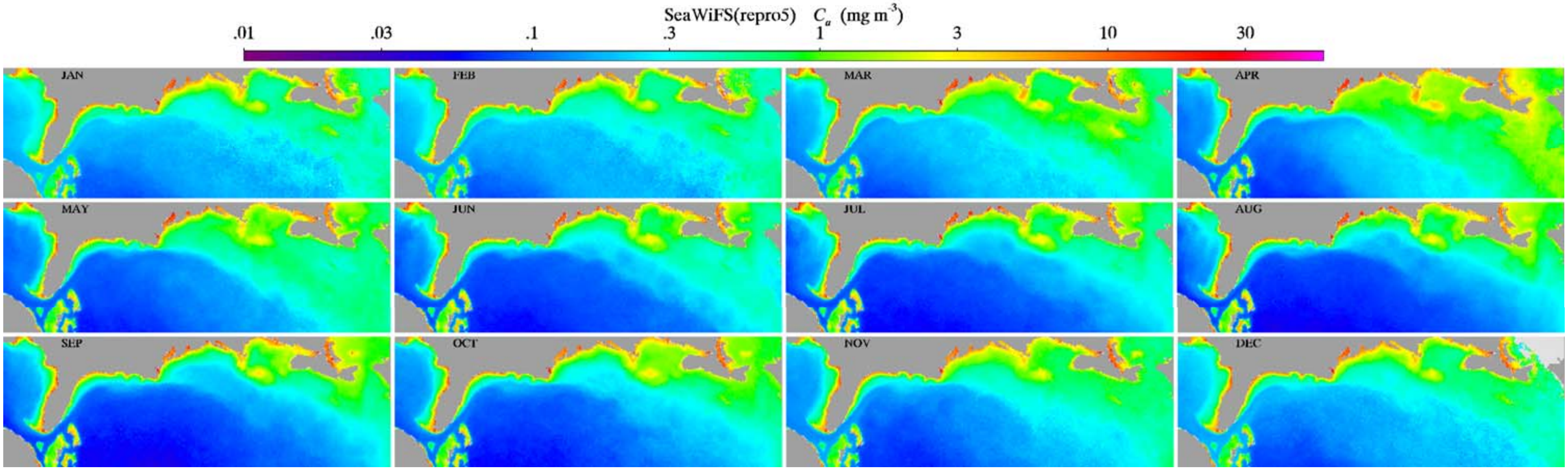
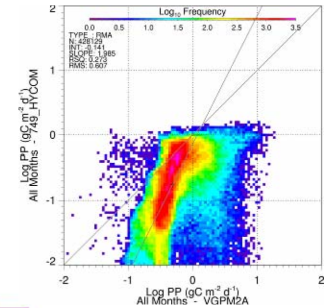
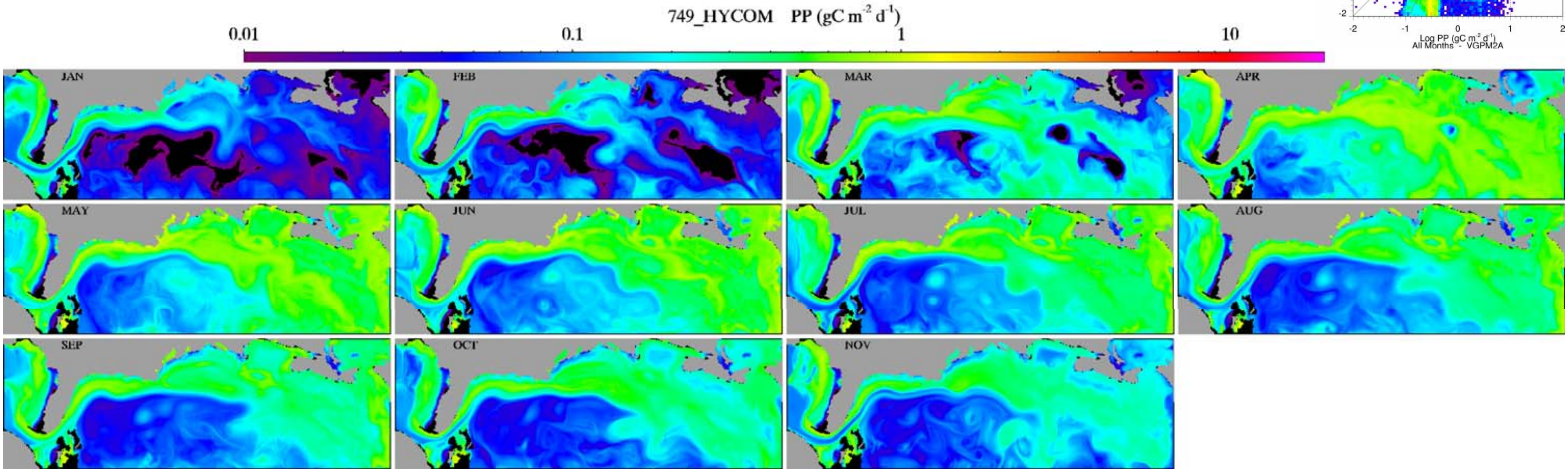
SLOPE: 1.348
RSQ: 0.290
RMS: 0.535
Log Chlor_a (mg m-3)
All Months - 749_HYCOM
Log Chlor_a (mg m-3)
All Months - REPRO5
2 1 0 -1 -2
-2 -1 0 1 2

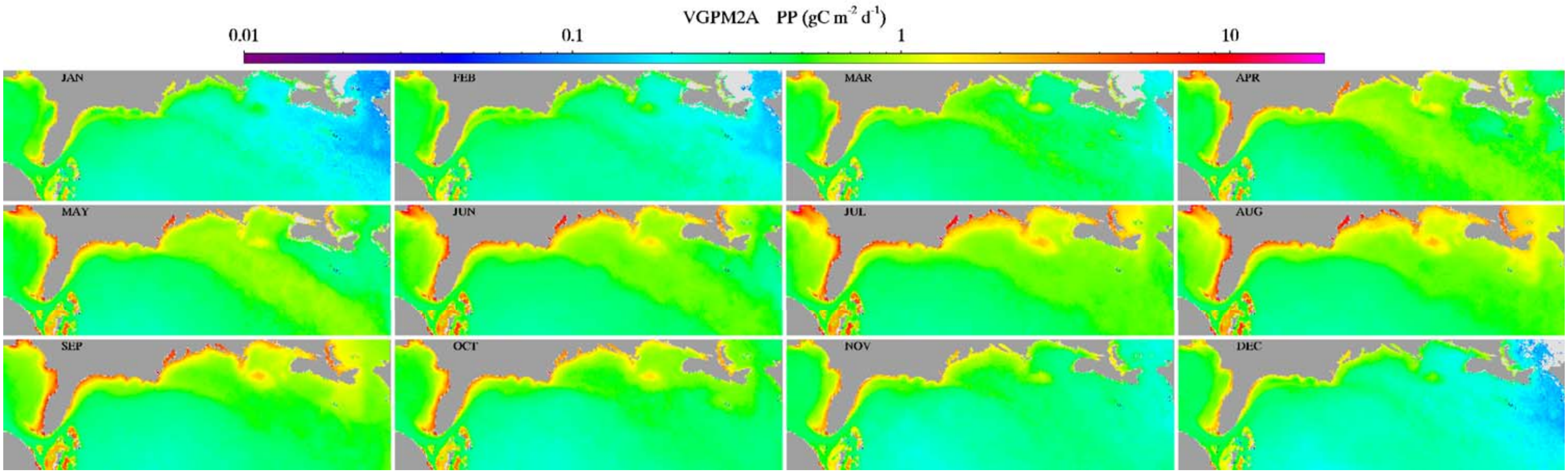

ROMS(749_hycom) C_a (mg m-3)
.01 .03 .1 .3 1 3 10 30
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC


SeaWiFS(repro5) C_a (mg m-3)
.01 .03 .1 .3 1 3 10 30
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

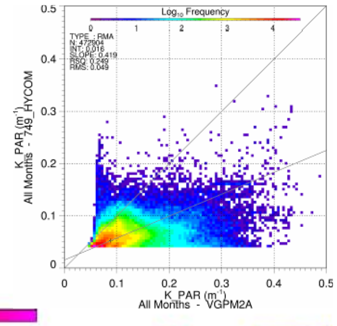
Primary Production







K_PAR


Log10 Frequency
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1
2
3
4
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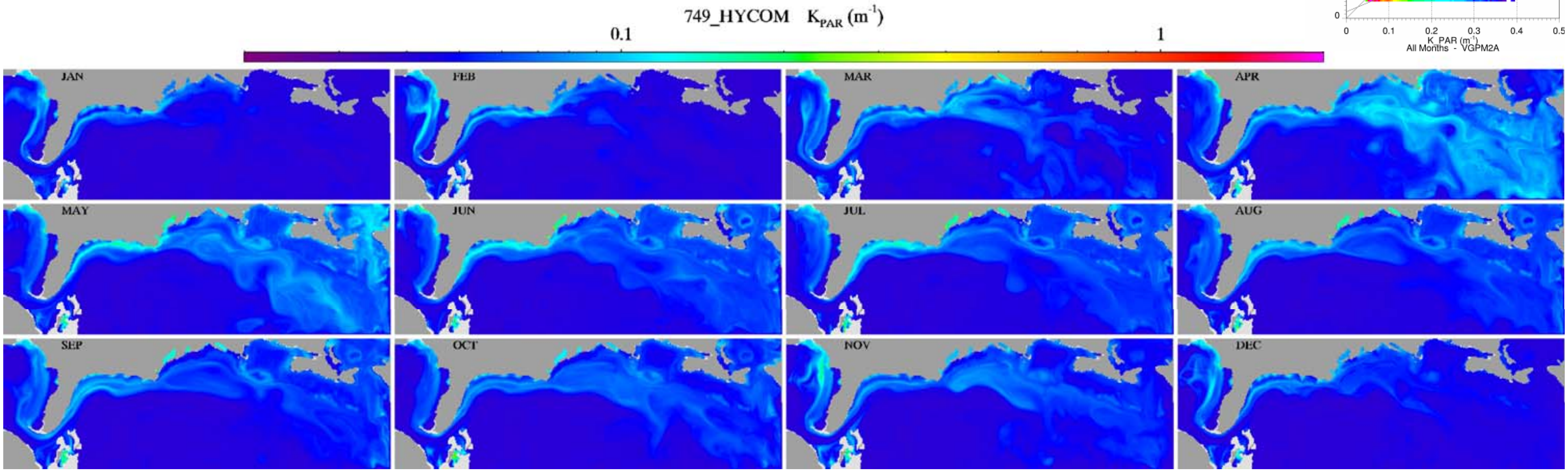
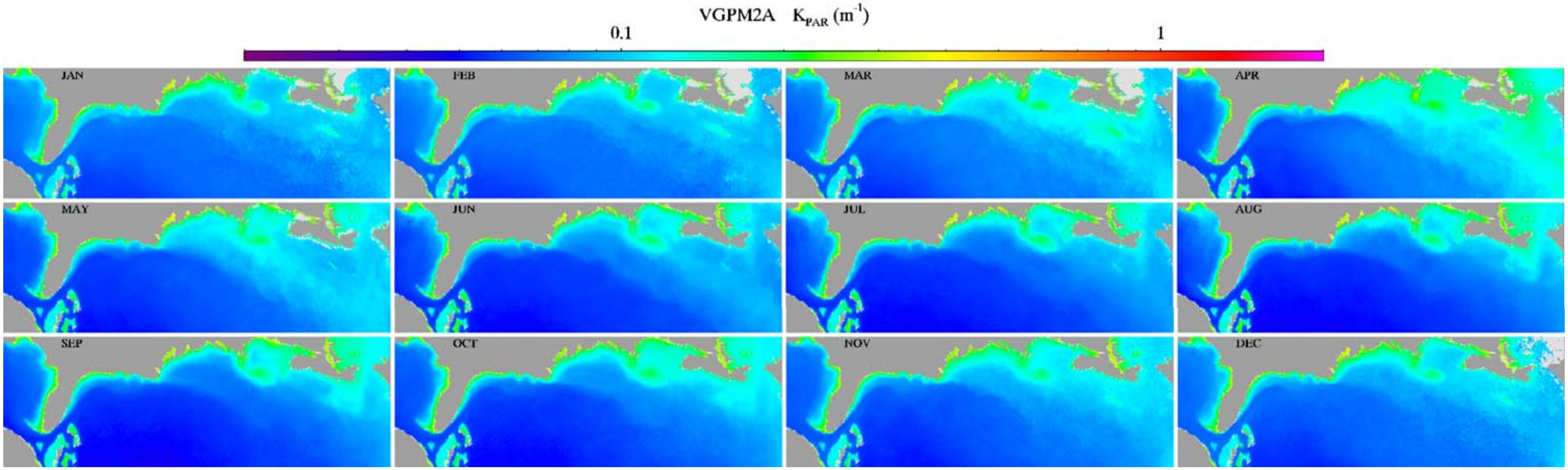
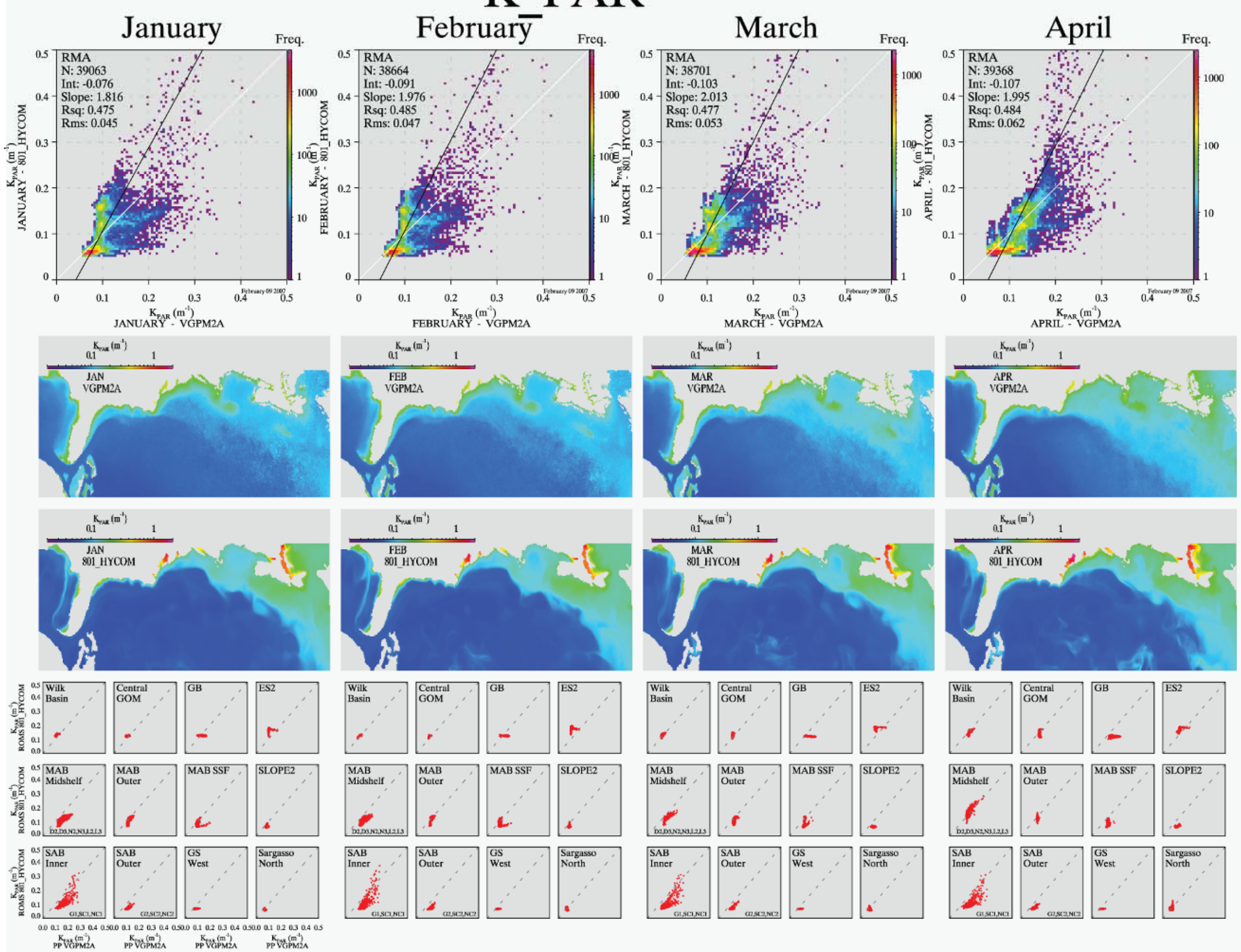
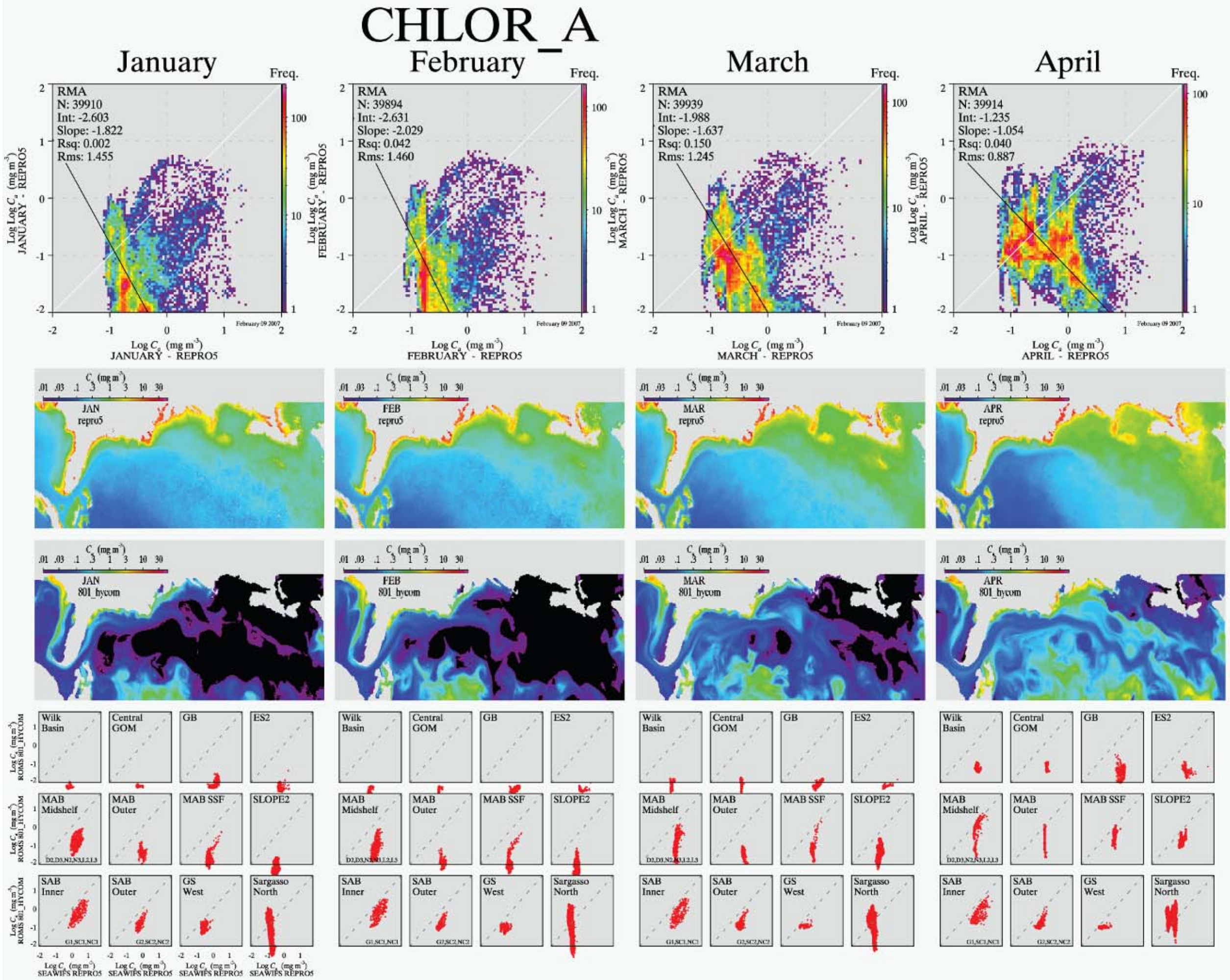
N: 472904
INT: 0.016
SLOPE: 0.419
RSQ: 0.249
RMS: 0.049
K_PAR (m-1)
All Months - 749_HYCOM
K_PAR (m-1)
All Months - VGPM2A
0
0.1
0.2
0.3
0.4
0.5


749_HYCOM K_PAR (m-1)
0.1
1
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

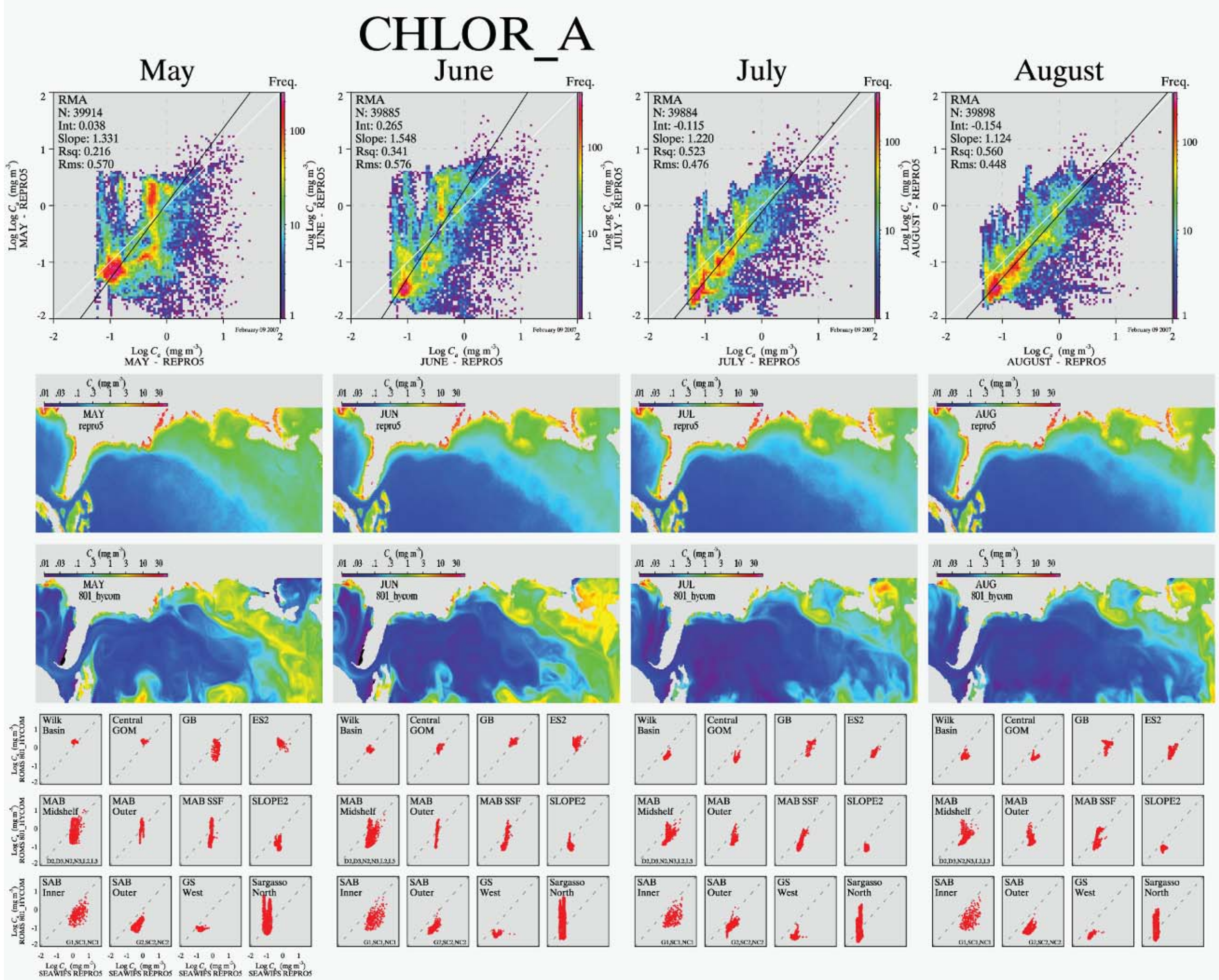

VGPM2A K_PAR (m-1)
0.1
1
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

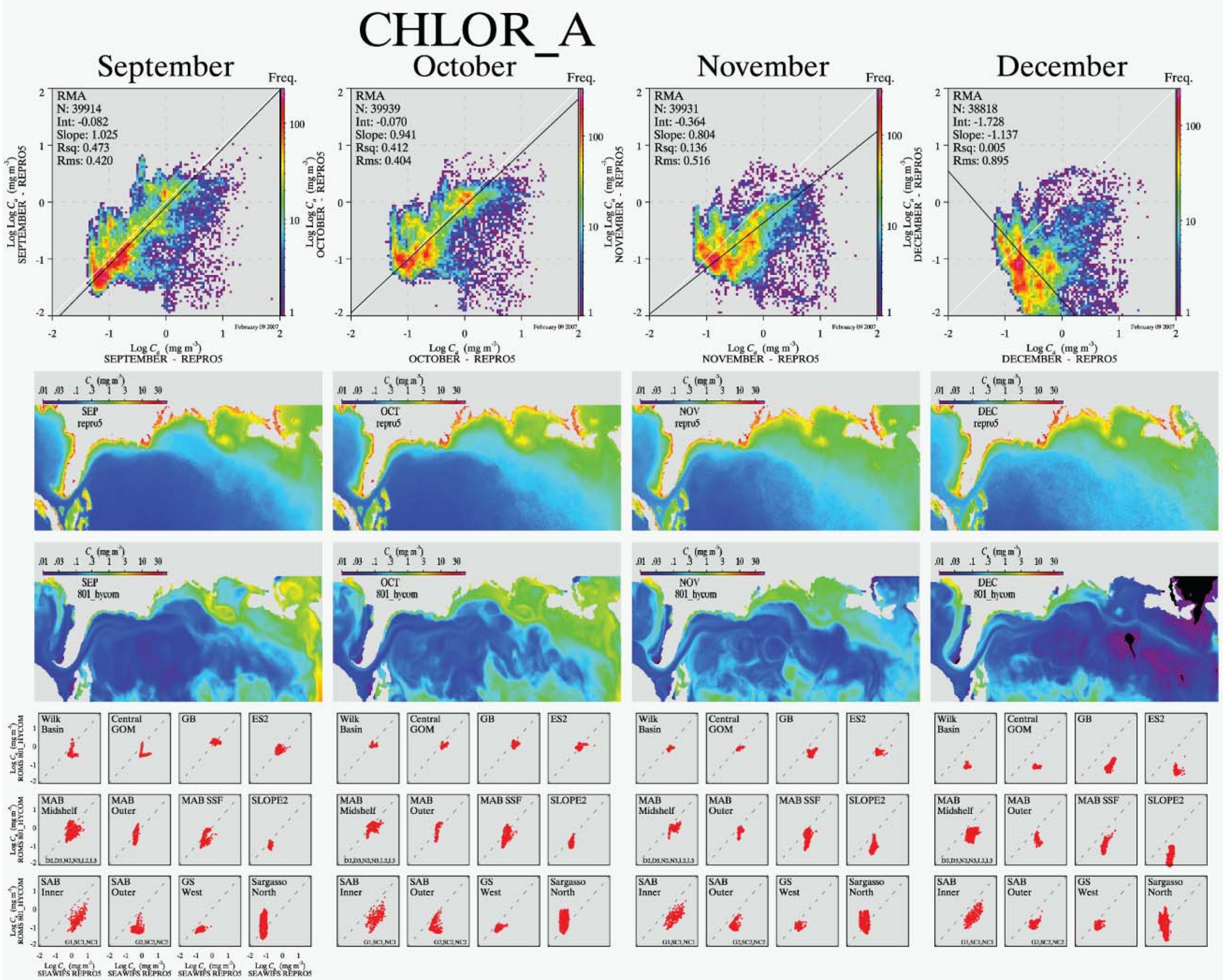
K_PAR

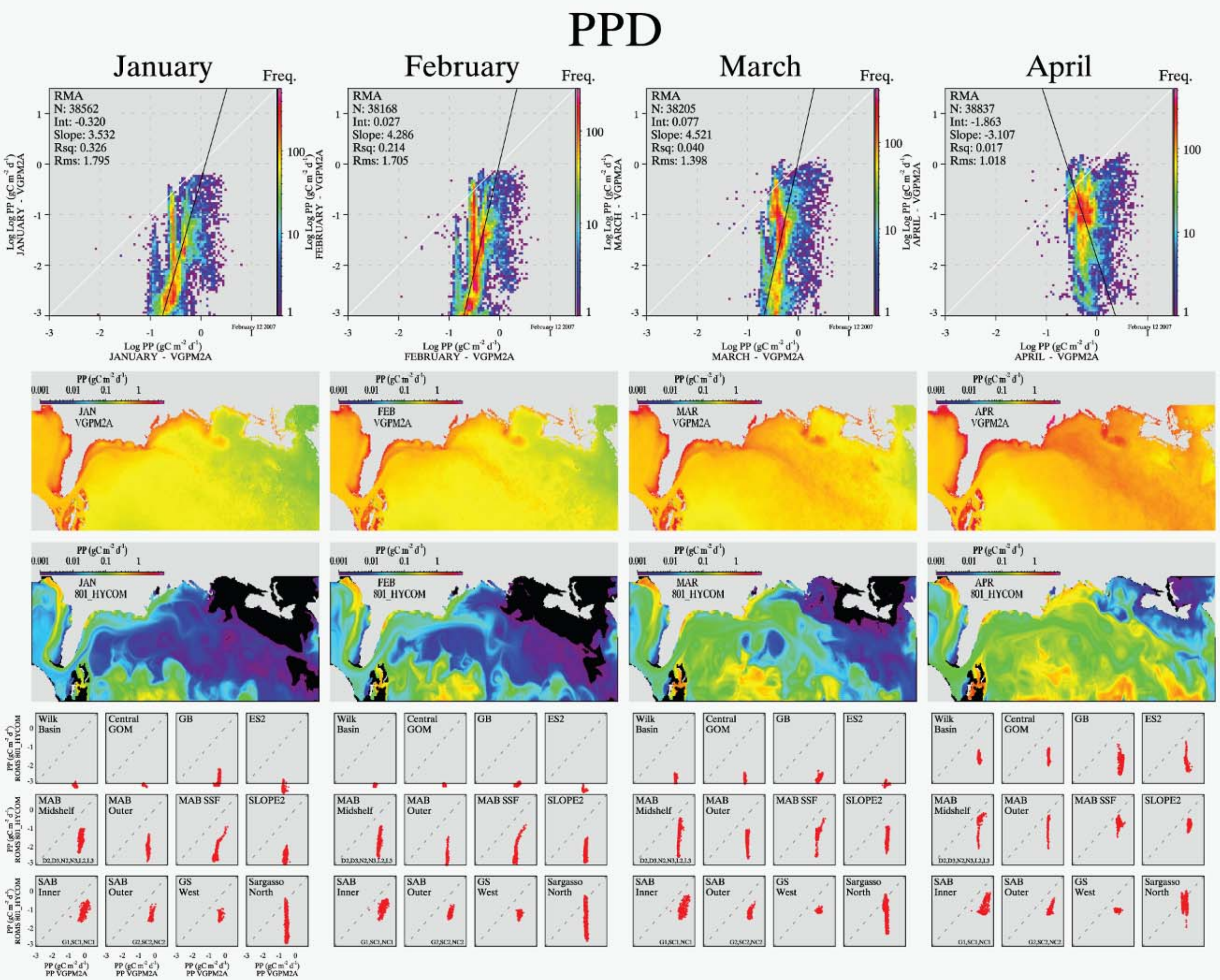

January
February
March
April
Freq.
RMA
N: 39063
Int: -0.076
Slope: 1.816
Rsq: 0.475
Rms: 0.045
RMA
N: 38664
Int: -0.091
Slope: 1.976
Rsq: 0.485
Rms: 0.047
RMA
N: 38701
Int: -0.103
Slope: 2.013
Rsq: 0.477
Rms: 0.053
RMA
N: 39368
Int: -0.107
Slope: 1.995
Rsq: 0.484
Rms: 0.062
JANUARY - VGPM2A
FEBRUARY - VGPM2A
MARCH - VGPM2A
APRIL - VGPM2A
JAN VGPM2A
FEB VGPM2A
MAR VGPM2A
APR VGPM2A
JAN 801_HYCOM
FEB 801_HYCOM
MAR 801_HYCOM
APR 801_HYCOM
Wilk Basin
Central GOM
GB
ES2
MAB Midshelf
MAB Outer
MAB SSF
SLOPE2
SAB Inner
SAB Outer
GS West
Sargasso North
PP VGPM2A

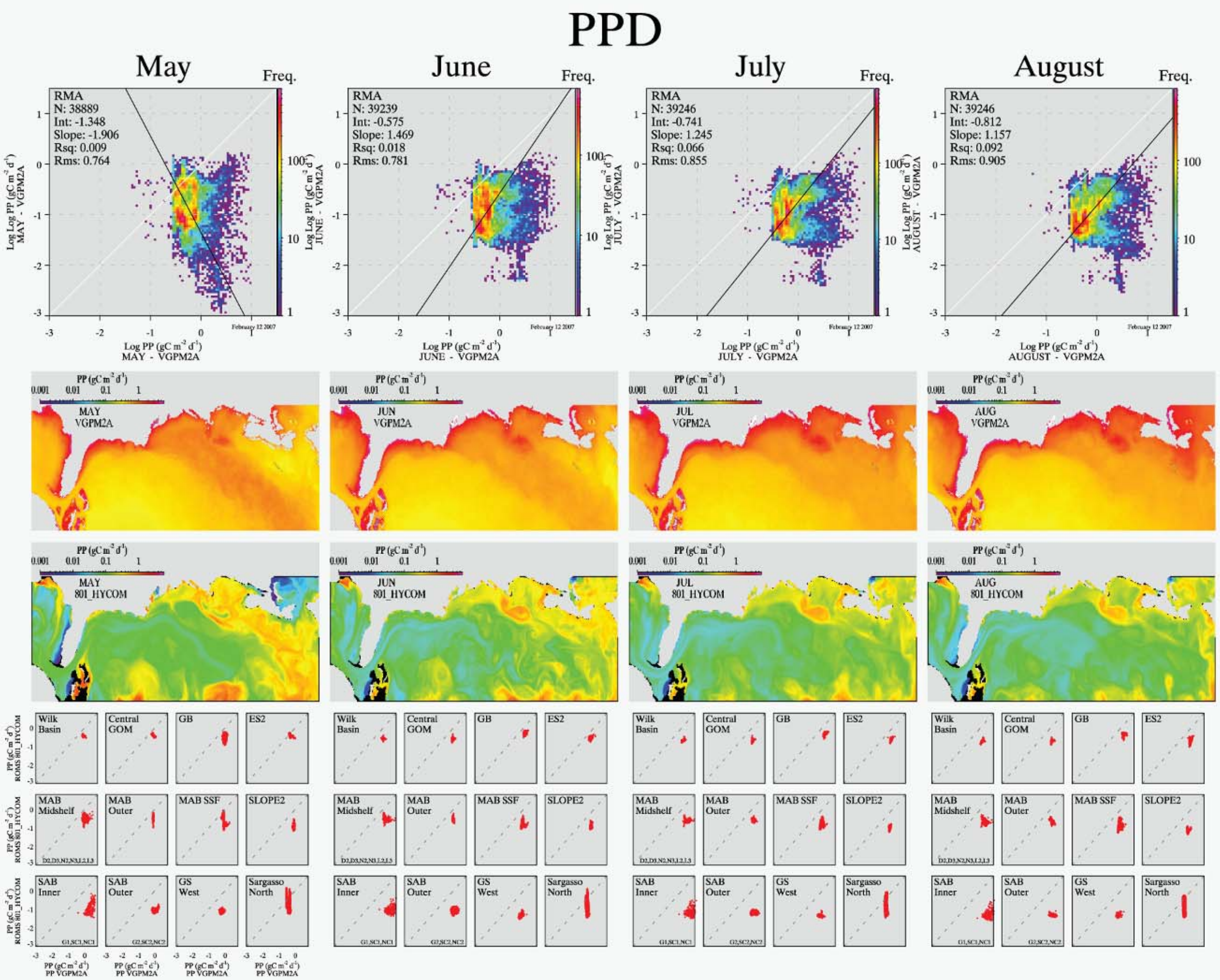


CHLOR_A
January
February
March
April
Freq.
RMA
N: 39910
Int: -2.603
Slope: -1.822
Rsq: 0.002
Rms: 1.455
N: 39894
Int: -2.631
Slope: -2.029
Rsq: 0.042
Rms: 1.460
N: 39939
Int: -1.988
Slope: -1.637
Rsq: 0.150
Rms: 1.245
N: 39914
Int: -1.235
Slope: -1.054
Rsq: 0.040
Rms: 0.887
JANUARY - REPRO5
FEBRUARY - REPRO5
MARCH - REPRO5
APRIL - REPRO5
JAN repro5
FEB repro5
MAR repro5
APR repro5
JAN 801_hycom
FEB 801_hycom
MAR 801_hycom
APR 801_hycom
Wilk Basin
Central GOM
GB
ES2
MAB Midshelf
MAB Outer
MAB SSF
SLOPE2
SAB Inner
SAB Outer
GS West
Sargasso North
SEAWIFS REPRO5


CHLOR_A
May
June
July
August
RMA
N: 39914
Int: 0.038
Slope: 1.331
Rsq: 0.216
Rms: 0.570
RMA
N: 39885
Int: 0.265
Slope: 1.548
Rsq: 0.341
Rms: 0.576
RMA
N: 39884
Int: -0.115
Slope: 1.220
Rsq: 0.523
Rms: 0.476
RMA
N: 39898
Int: -0.154
Slope: 1.124
Rsq: 0.560
Rms: 0.448
Freq.
MAY - REPRO5
JUNE - REPRO5
JULY - REPRO5
AUGUST - REPRO5
MAY repro5
JUN repro5
JUL repro5
AUG repro5
MAY 801_hycom
JUN 801_hycom
JUL 801_hycom
AUG 801_hycom
Wilk Basin
Central GOM
GB
ES2
MAB Midshelf
MAB Outer
MAB SSF
SLOPE2
SAB Inner
SAB Outer
GS West
Sargasso North
SEAWIFS REPRO5

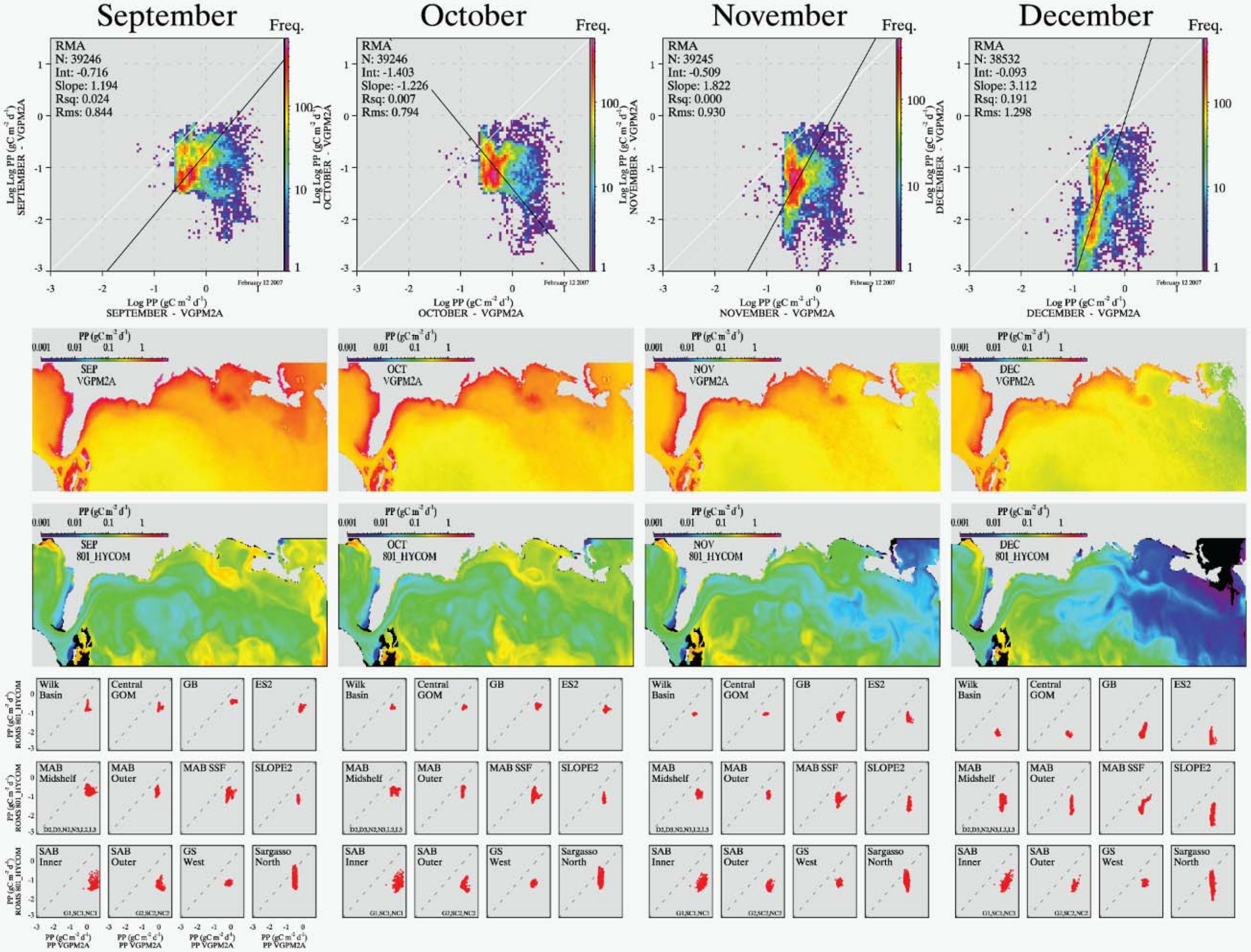

CHLOR_A
September
October
November
December
Freq.
RMA
N: 39914
Int: -0.082
Slope: 1.025
Rsq: 0.473
Rms: 0.420
RMA
N: 39939
Int: -0.070
Slope: 0.941
Rsq: 0.412
Rms: 0.404
RMA
N: 39931
Int: -0.364
Slope: 0.804
Rsq: 0.136
Rms: 0.516
RMA
N: 38818
Int: -1.728
Slope: -1.137
Rsq: 0.005
Rms: 0.895
SEPTEMBER - REPRO5
OCTOBER - REPRO5
NOVEMBER - REPRO5
DECEMBER - REPRO5
SEP repro5
OCT repro5
NOV repro5
DEC repro5
SEP 801_hycom
OCT 801_hycom
NOV 801_hycom
DEC 801_hycom
Wilk Basin
Central GOM
GB
ES2
MAB Midshelf
MAB Outer
MAB SSF
SLOPE2
SAB Inner
SAB Outer
GS West
Sargasso North
SEAWIFS REPRO5


PPD
January
February
March
April
Freq.
RMA
N: 38562
Int: -0.320
Slope: 3.532
Rsq: 0.326
Rms: 1.795
RMA
N: 38168
Int: 0.027
Slope: 4.286
Rsq: 0.214
Rms: 1.705
RMA
N: 38205
Int: 0.077
Slope: 4.521
Rsq: 0.040
Rms: 1.398
RMA
N: 38837
Int: -1.863
Slope: -3.107
Rsq: 0.017
Rms: 1.018
Log PP (gC m^-2 d^-1)
JANUARY - VGPM2A
FEBRUARY - VGPM2A
MARCH - VGPM2A
APRIL - VGPM2A
PP (gC m^-2 d^-1)
JAN VGPM2A
FEB VGPM2A
MAR VGPM2A
APR VGPM2A
JAN 801_HYCOM
FEB 801_HYCOM
MAR 801_HYCOM
APR 801_HYCOM
Wilk Basin
Central GOM
GB
ES2
MAB Midshelf
MAB Outer
MAB SSF
SLOPE2
SAB Inner
SAB Outer
GS West
Sargasso North
PP (gC m^-2 d^-1) ROMS 801_HYCOM
PP (gC m^-2 d^-1) PP VGPM2A



PPD
May
June
July
August
Freq.
RMA
N: 38889
Int: -1.348
Slope: -1.906
Rsq: 0.009
Rms: 0.764
RMA
N: 39239
Int: -0.575
Slope: 1.469
Rsq: 0.018
Rms: 0.781
RMA
N: 39246
Int: -0.741
Slope: 1.245
Rsq: 0.066
Rms: 0.855
RMA
N: 39246
Int: -0.812
Slope: 1.157
Rsq: 0.092
Rms: 0.905
Log PP (gC m-2 d-1)
MAY - VGPM2A
JUNE - VGPM2A
JULY - VGPM2A
AUGUST - VGPM2A
MAY 801_HYCOM
JUN 801_HYCOM
JUL 801_HYCOM
AUG 801_HYCOM
Wilk Basin
Central GOM
GB
ES2
MAB Midshelf
MAB Outer
MAB SSF
SLOPE2
SAB Inner
SAB Outer
GS West
Sargasso North
PP VGPM2A

PPD


September
October
November
December
Freq.
RMA
N: 39246
Int: -0.716
Slope: 1.194
Rsq: 0.024
Rms: 0.844
RMA
N: 39246
Int: -1.403
Slope: -1.226
Rsq: 0.007
Rms: 0.794
RMA
N: 39245
Int: -0.509
Slope: 1.822
Rsq: 0.000
Rms: 0.930
RMA
N: 38532
Int: -0.093
Slope: 3.112
Rsq: 0.191
Rms: 1.298
Log PP (gC m⁻² d⁻¹)
SEPTEMBER - VGPM2A
OCTOBER - VGPM2A
NOVEMBER - VGPM2A
DECEMBER - VGPM2A
SEP VGPM2A
OCT VGPM2A
NOV VGPM2A
DEC VGPM2A
SEP 801_HYCOM
OCT 801_HYCOM
NOV 801_HYCOM
DEC 801_HYCOM
Wilk Basin
Central GOM
GB
ES2
MAB Midshelf
MAB Outer
MAB SSF
SLOPE2
SAB Inner
SAB Outer
GS West
Sargasso North
PP (gC m⁻² d⁻¹) ROMS 801_HYCOM
PP (gC m⁻² d⁻¹) PP VGPM2A

Problems

- PP too low overall
- Chlorophyll too low in winter, especially on the Scotian Shelf and in the Gulf of Maine
- Need to analyze: relative importance of different limiting factors; magnitude of source versus sink terms

The biological source and sinks in NENA are calculated according to the following equation:

$$\frac{\partial Phy}{\partial t} = \mu Phy - g\,Zoo - m_P Phy - \tau(SDet + Phy)Phy - w_P \frac{\partial Phy}{\partial z}$$

where the growth rate of phytoplankton, μ, depends on the temperature T through the maximum growth rate $\mu_{\max} = \mu_{\max}(T) = \mu_0 \cdot 1.066^T$ (Eppley 1972), on the photosynthetically available radiation I, and on the nutrient concentrations $NO3$ and $NH4$:

$\mu = \mu_{\max} \cdot f(I) \cdot (L_{NO3} + L_{NH4})$, where

$$L_{NO3} = \frac{NO3}{k_{NO3} + NO3} \cdot \frac{1}{1 + NH4/k_{NH4}}$$ and

$$L_{NH4} = \frac{NH4}{k_{NH4} + NH4}.$$

Primary productivity is equivalent to μPhy. If primary productivity is too small then either μ or *Phy* or both are too small. Also, especially in summer we would expect that a large fraction of μ to be supported by regenerated nutrients (i.e. NH4).

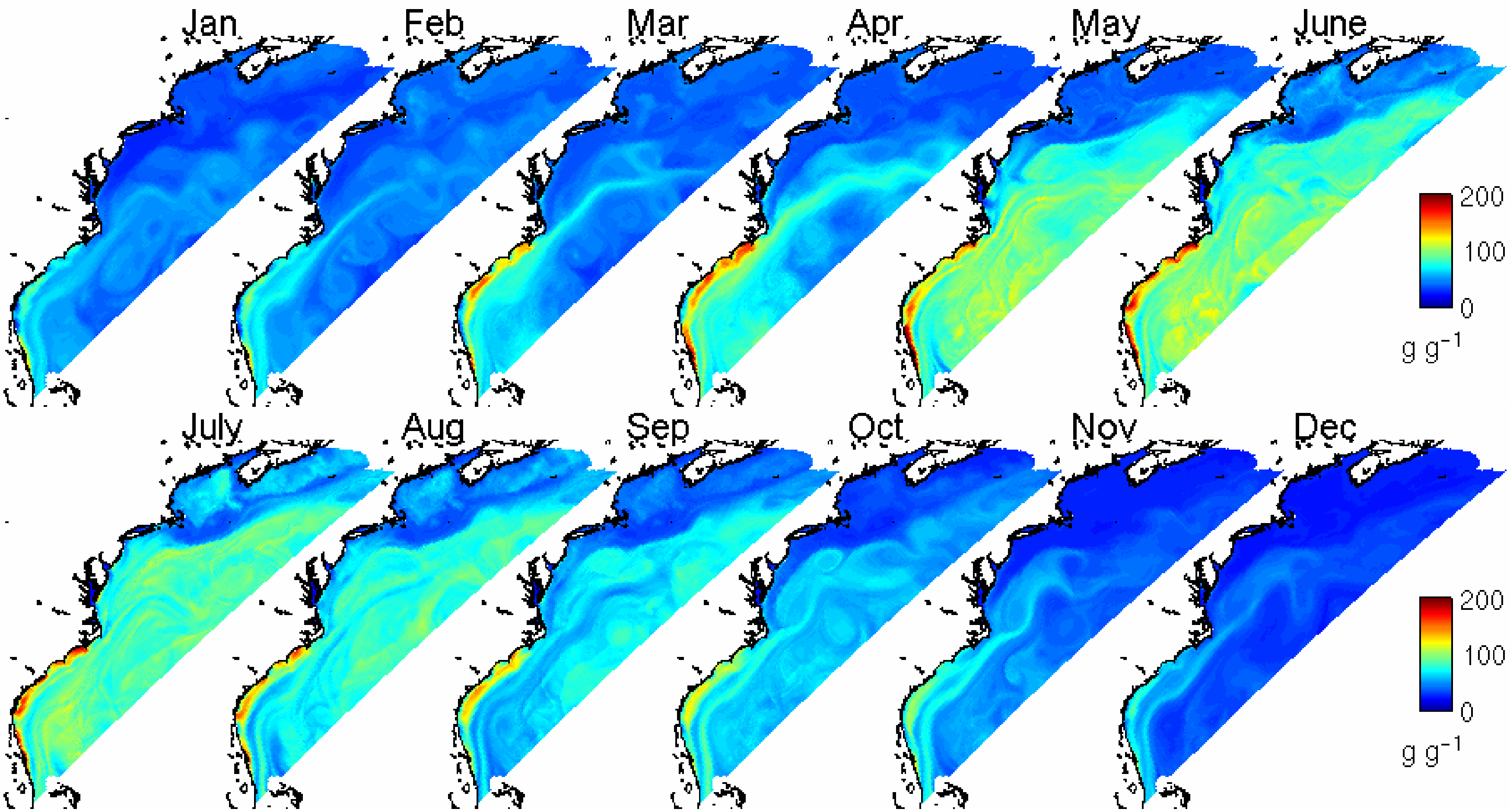
If *Phy* is too small, then either the source is too small or the sinks are too large or both.

In order to diagnose why PP is so small, we want to look at:
- the **f-ratio**: mean f-ratio over the whole water depth, also upper and lower euphotic zone [dimensionless; varies between 0 and 1]
- the **turnover time** of phytoplankton: biomass/PP or $1/\mu$ (euphotic zone mean, and mean of upper and lower euphotic zone) [day]
- the **ratio of C-to-Chl**: euphotic zone mean and mean for upper and lower euphotic zone [mg C/mg chl]
- the size of the different **limitation terms** entering μ

We also want to assess the relative importance of the different phytoplankton sink terms in comparison to the source term:
- **Primary Production**: μPhy, Depth-integrated [mmol N/m^2/day], and also mean for upper and lower euphotic zone [mmol N/m^3/day], so that we can directly compare to the sinks terms.
- Loss due to **aggregation, grazing** and **mortality:** depth-integrated [mmol N/m^2/day], as well as relative to PP and relative to total loss [dimensionless; varies between 0 and 1]

We define upper and lower euphotic zone as 100% to 10% light level and for 10% to 1% light level.

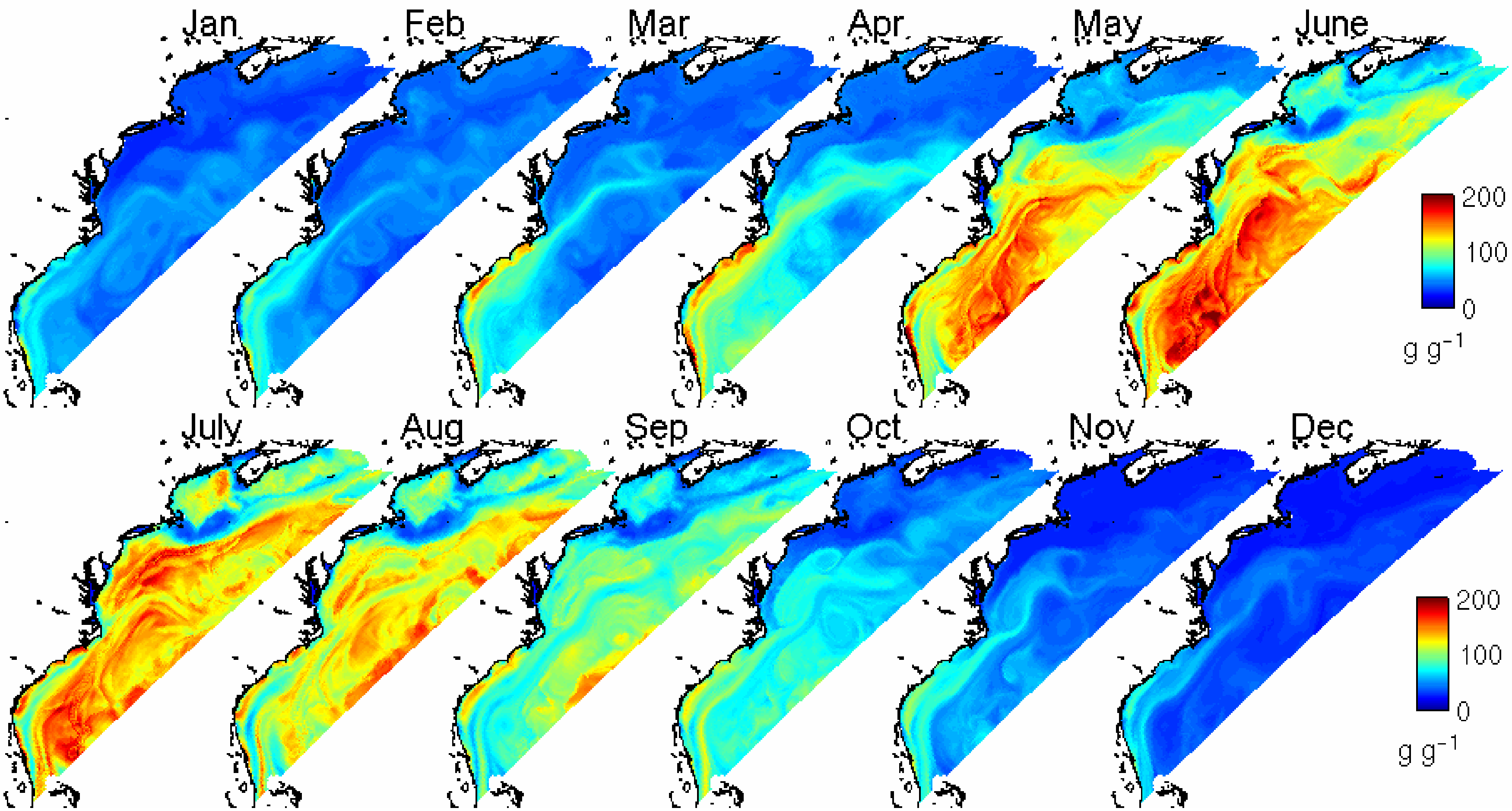
Mean euphotic C-to-Chl ratio (phyC-to-Chl)



POC/Chl varies from 25 to 400. Mean water column value for the MAB shelf is 40 (O'Reilly). In the oligotrophic ocean surface values reach 400 and DCM values go down to 50 (Stn. ALOHA).

Variations in C/Chl are systematic and reflect photoacclimation and changes species composition.

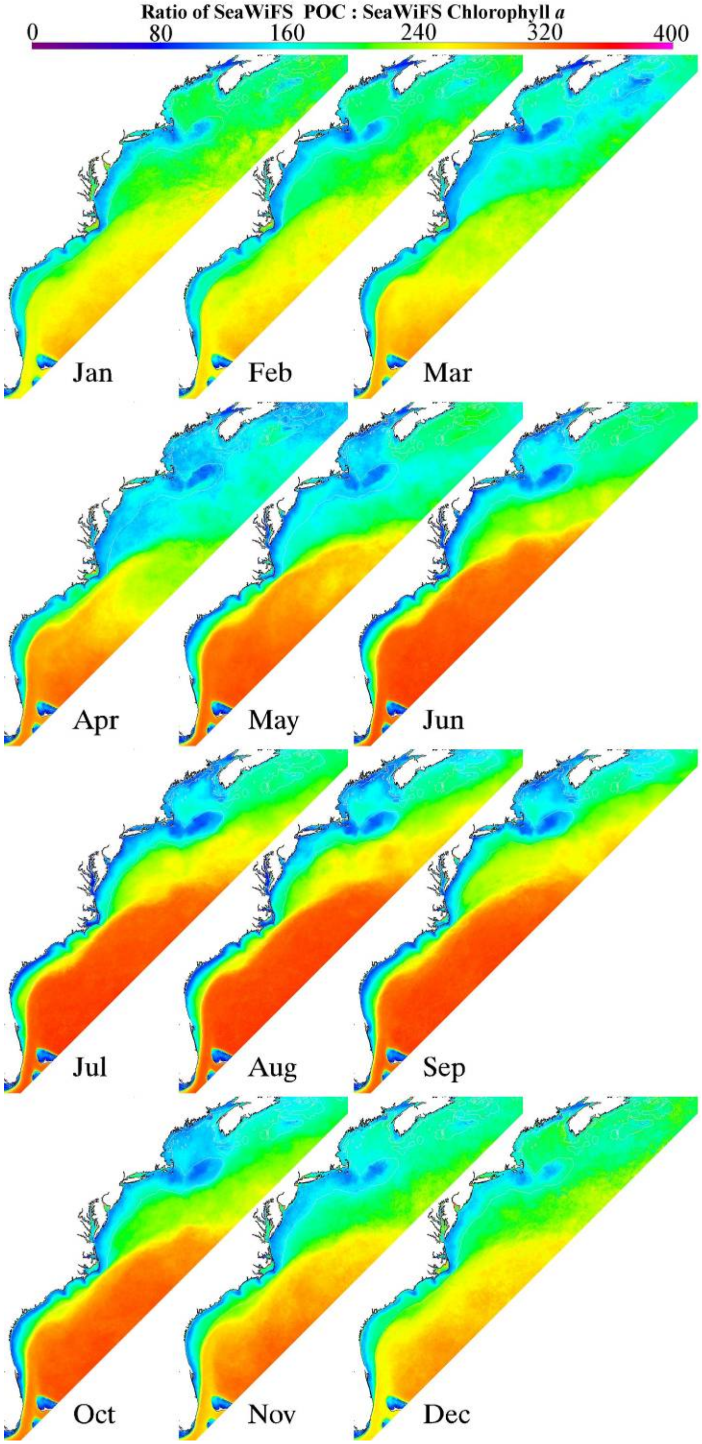
Upper euphotic C-to-Chl ratio (phyC-to-Chl)

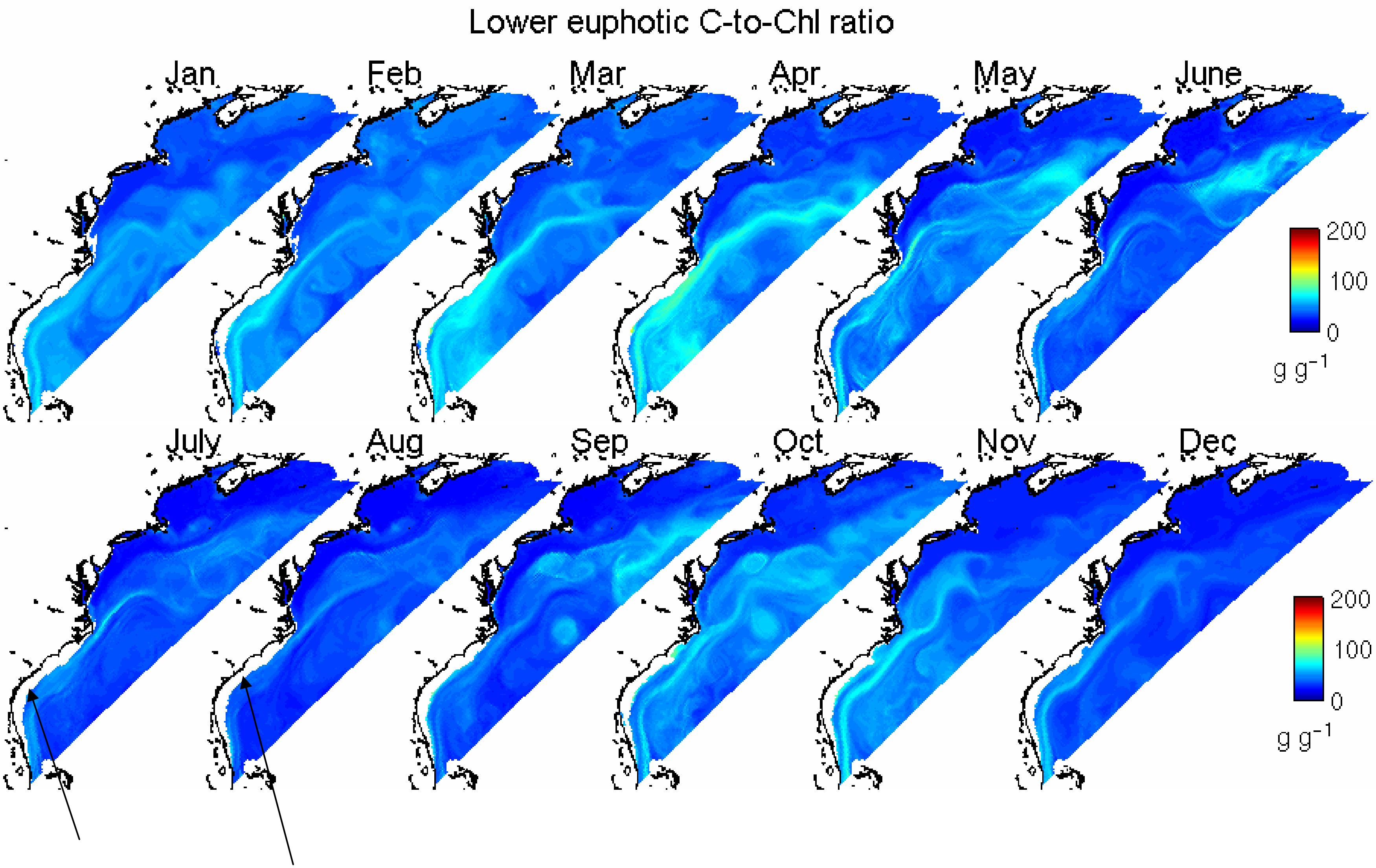


Ratios of phyC-to-chl on MAB shelf in summer (Falkowski et al. 1983):

108 in upper mixed layer

50 in subsurface chlorophyll maximum


Ratio of SeaWiFS POC : SeaWiFS Chlorophyll a
0
80
160
240
320
400
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec



Consistently more than 1% of surface light reaches the sediment in the SAB.

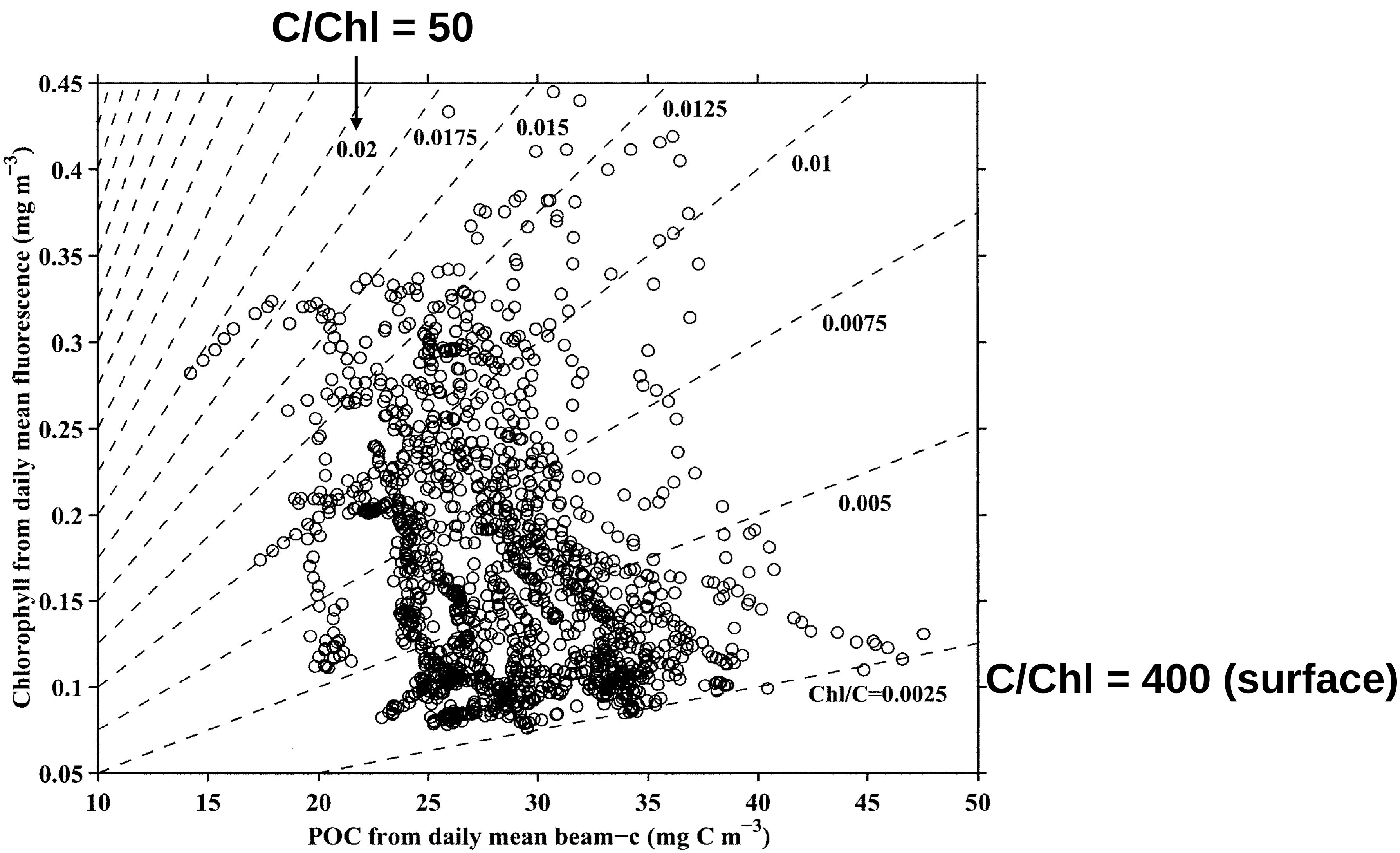
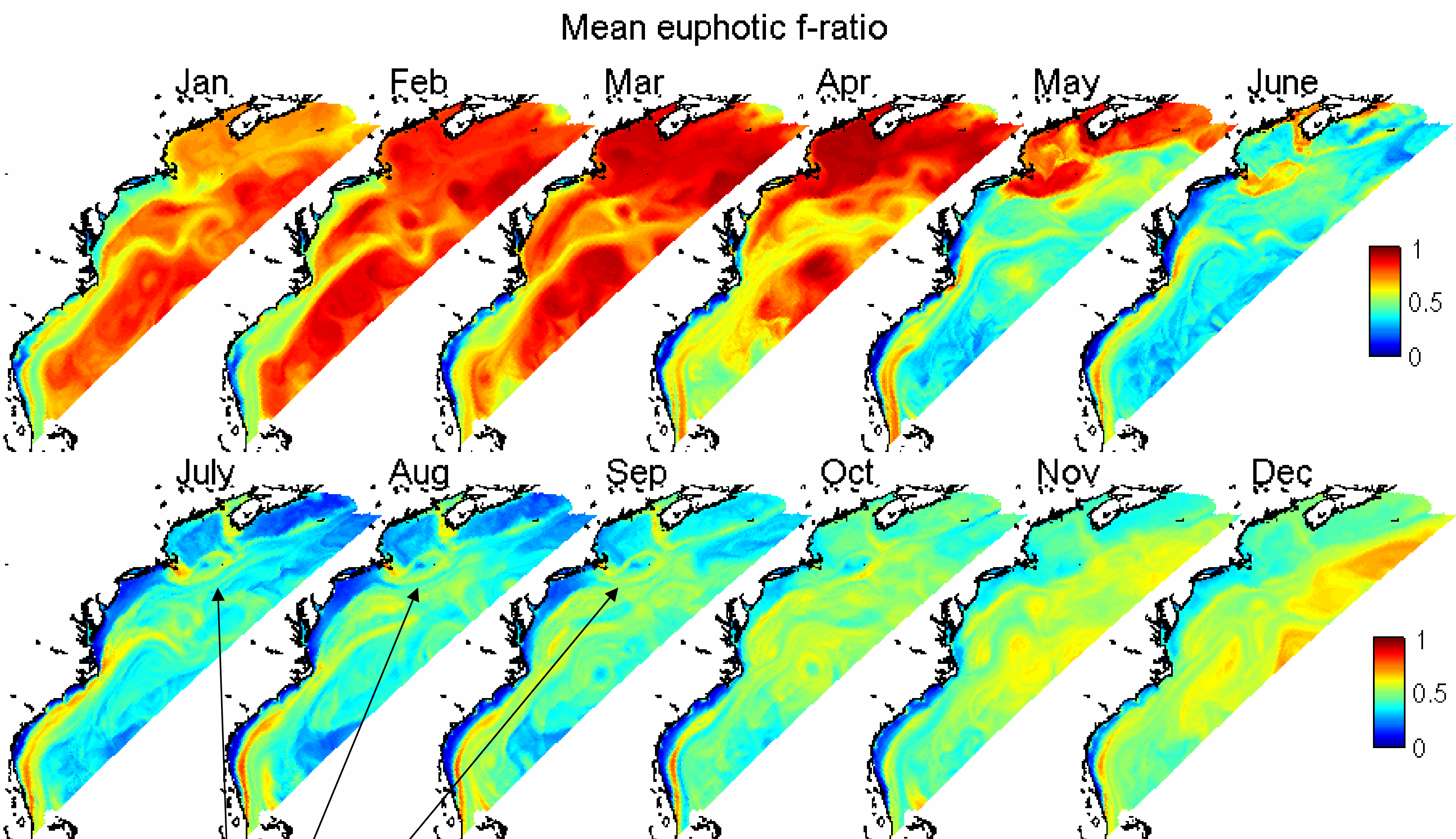
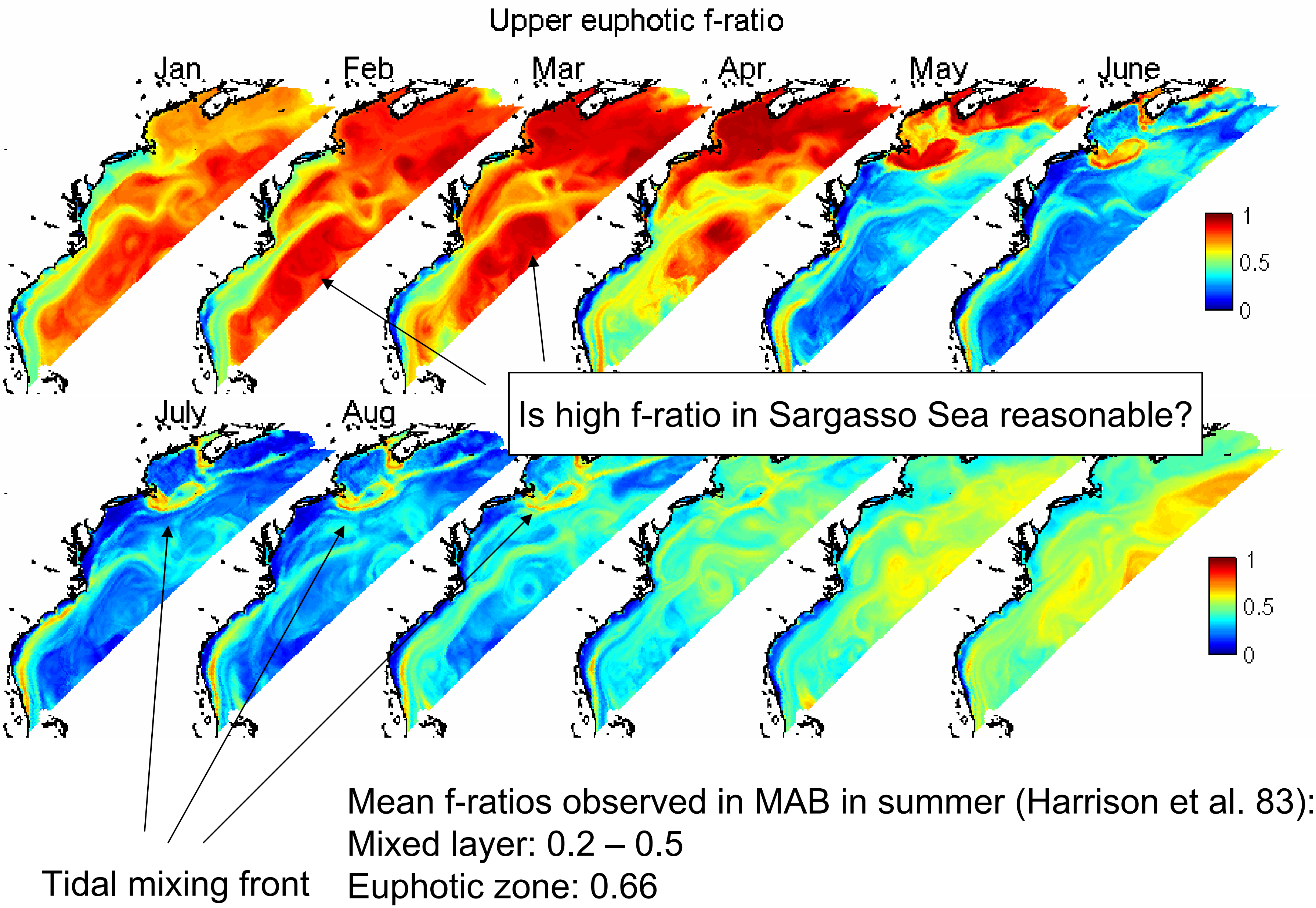


Fig. 5. Chlorophyll versus POC concentrations at Sta. ALOHA. Isolines of Chl : POC in g Chl (g C)$^{-1}$ are given as dashed lines. Chlorophyll and POC concentrations were obtained from daily mean profiles of fluorescence and beam attenuation. Each profile represents an average of ~10 casts. Data collected between August 1991 and July 1995 in the upper 120 m are shown.

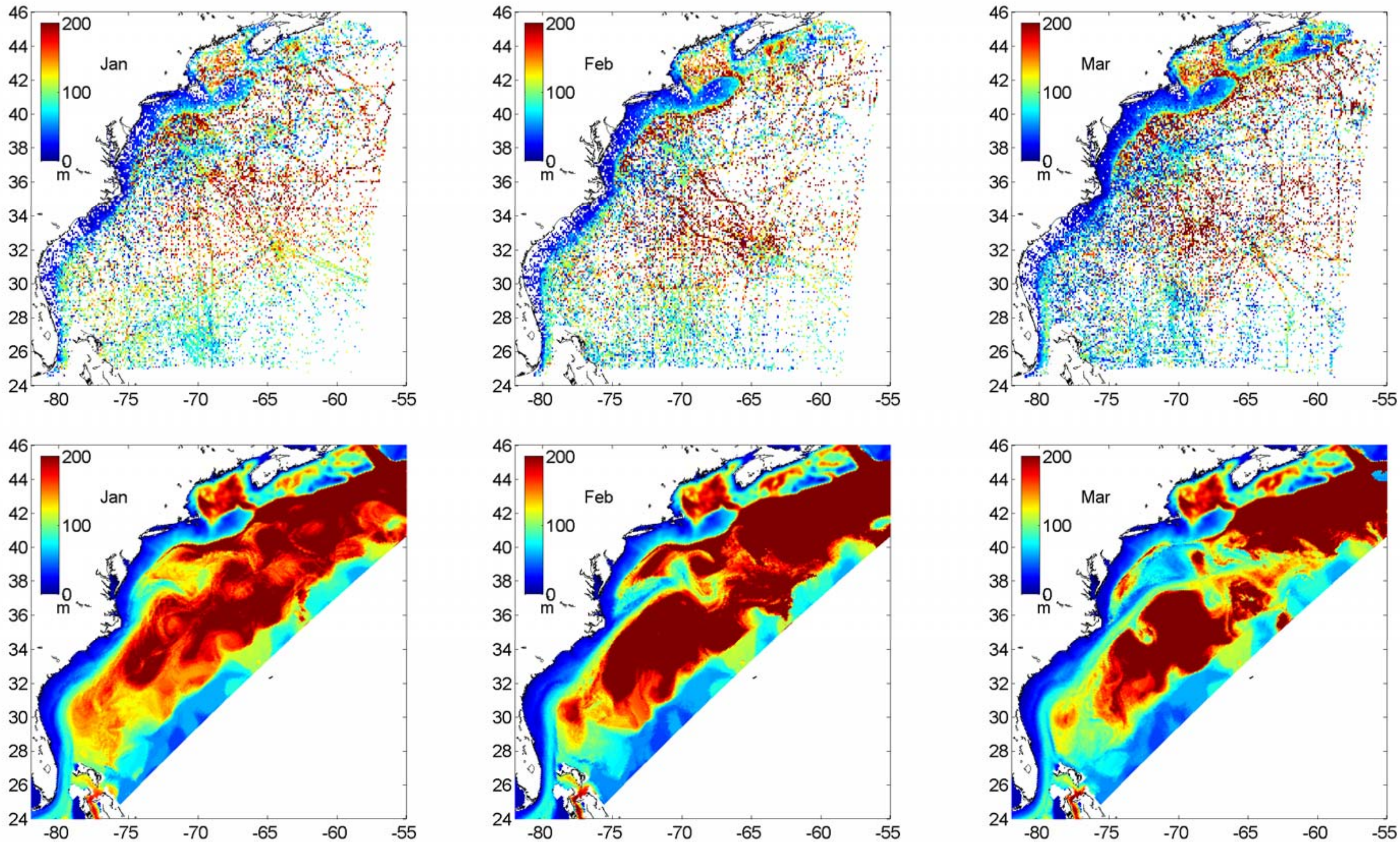


Spatial and temporal patterns seem reasonable

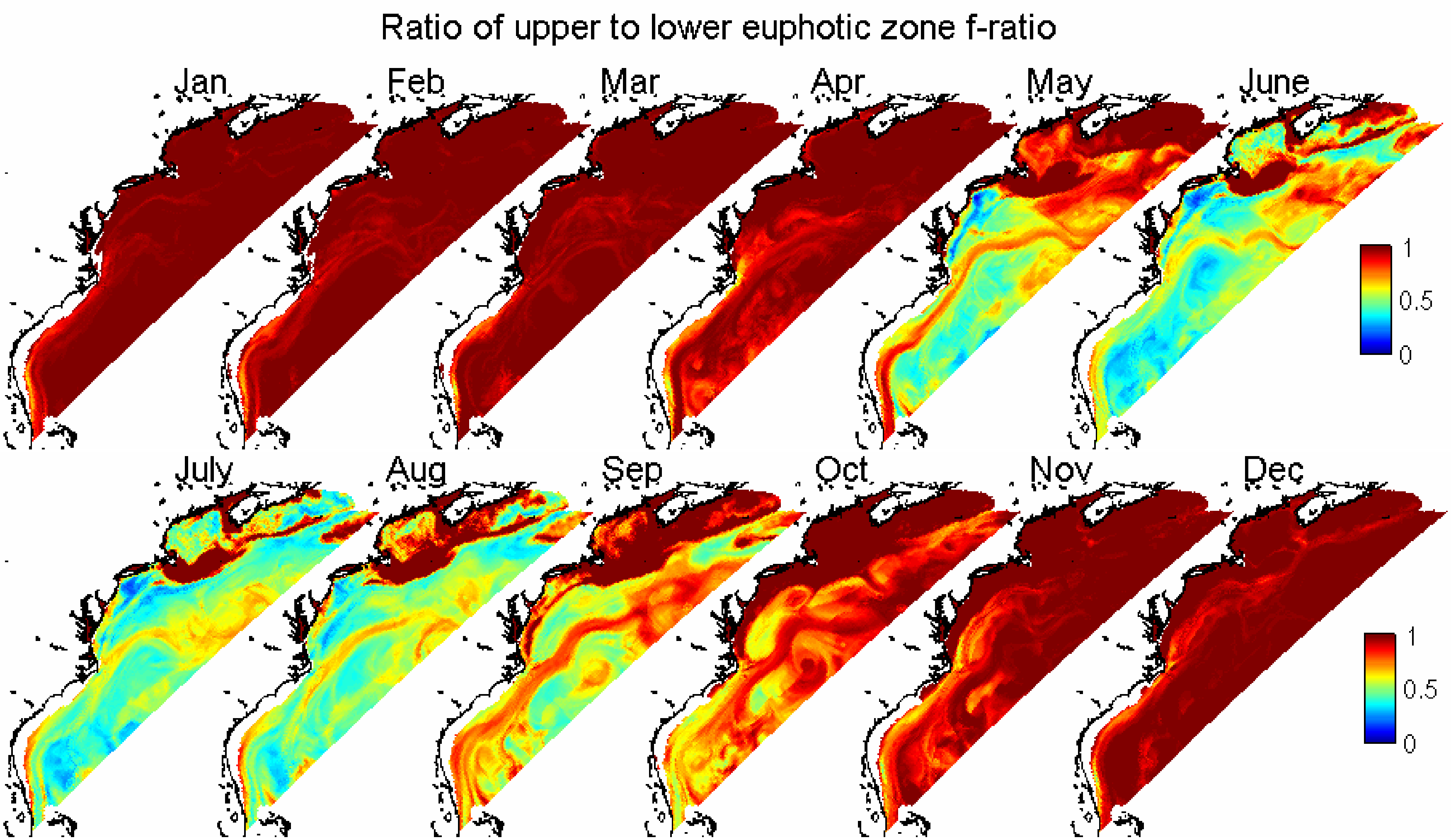
Tidally mixed areas (yellow band is mixing front)
Even more pronounced when looking at the upper euphotic zone (next slide)



Mean f-ratios observed in MAB in summer (Harrison et al. 83):
Mixed layer: 0.2 – 0.5
Euphotic zone: 0.66



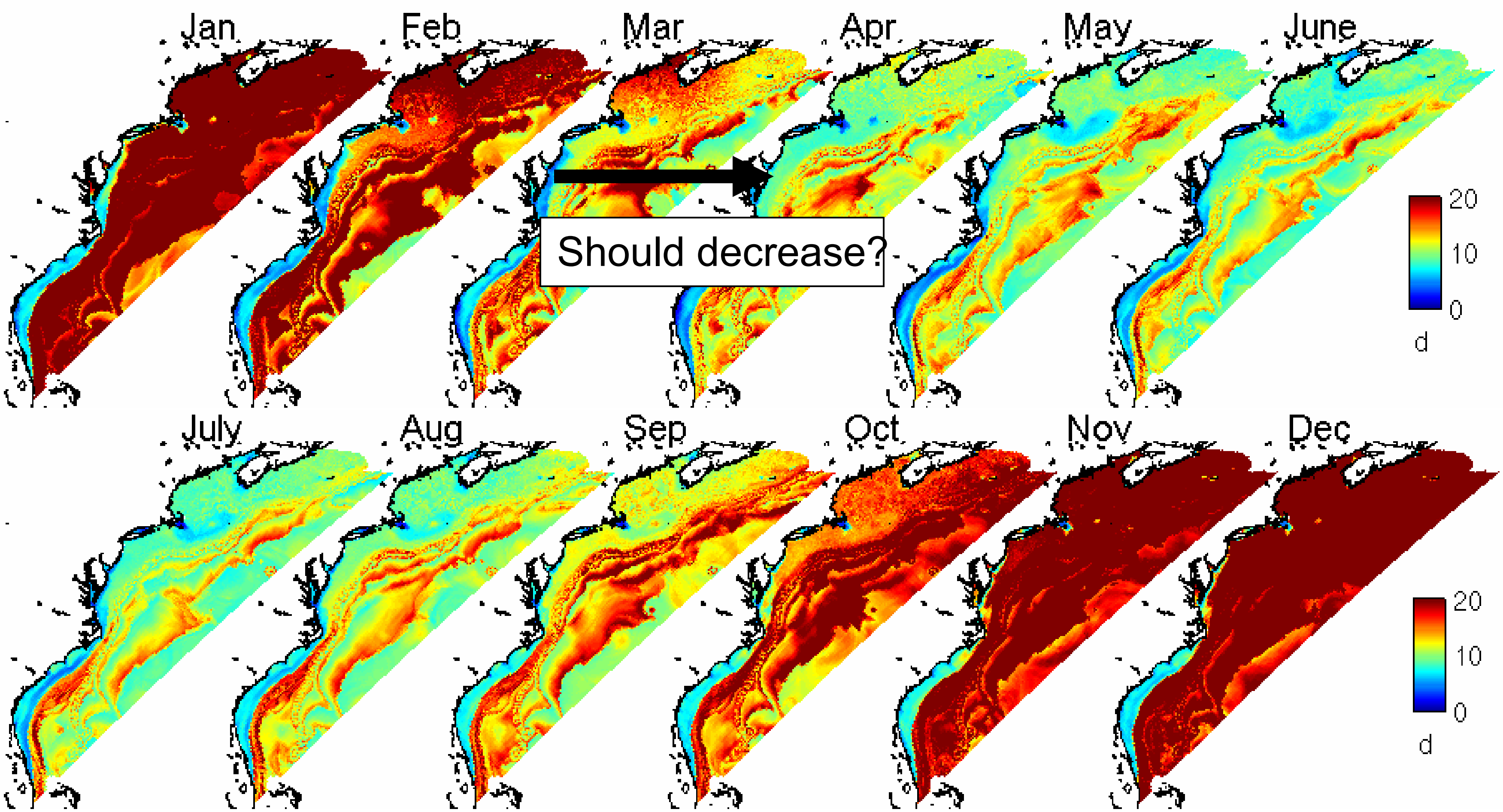
Mixed layer depth (top row: climatology; bottom row nena801) (0.05^{o}C criterion)



1: f-ratio is the same in upper and lower euphotic zone

<1: f-ratio in the upper euphotic zone is smaller than in the lower euphotic zone

Mean euphotic turnover time



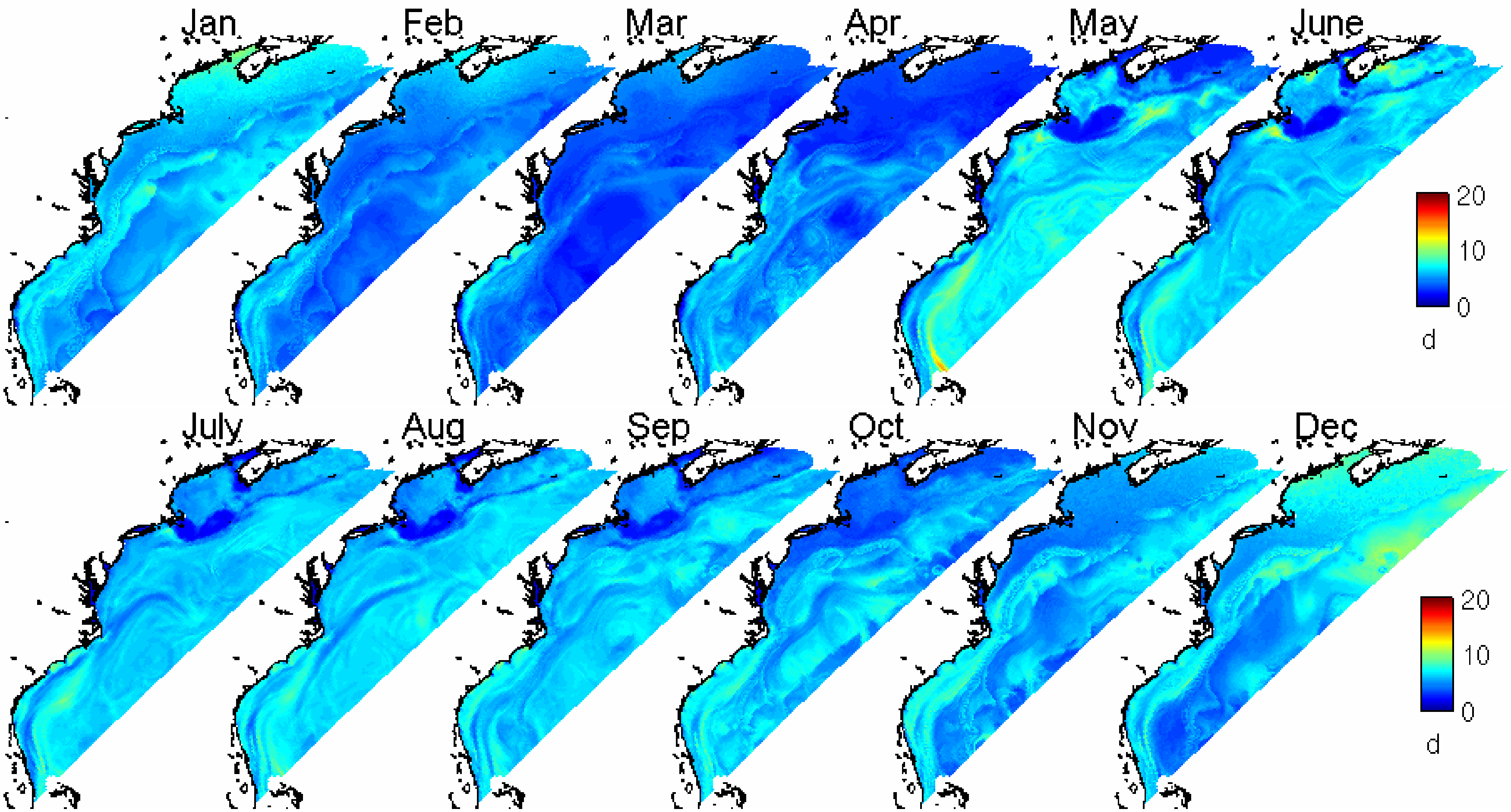
Mean turnover time for shelf systems (Gasol et al.) : 2 d

Summer observations for the MAB (Falkowski et al. 83): 4 ± 2 d (mixed layer)

14 ± 12 d (lower eu. Z.)

Increase in turnover time on the shelf (as opposed to the expected decrease) is indication of insufficient regenerated production in summer.

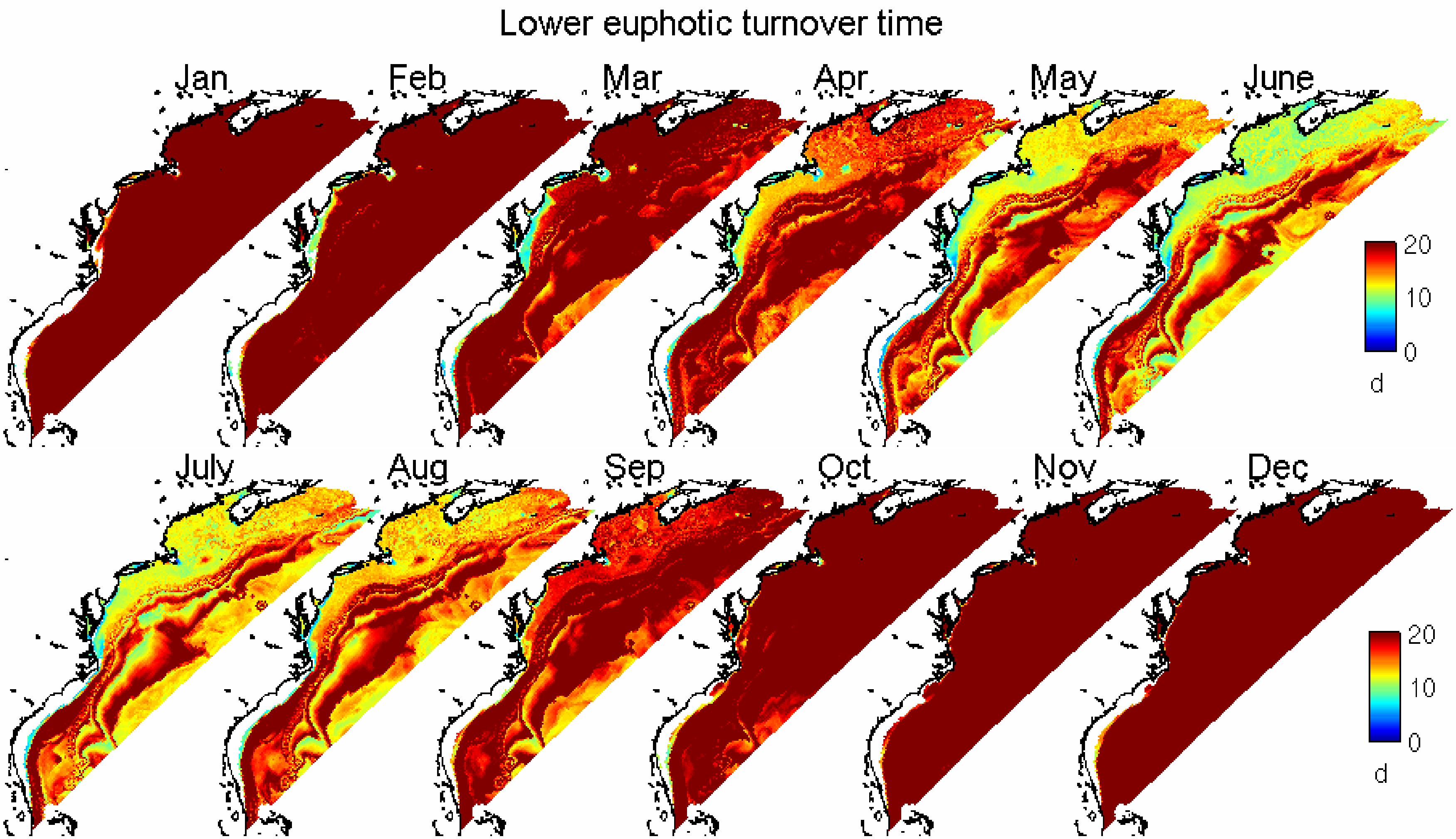
Upper euphotic turnover time

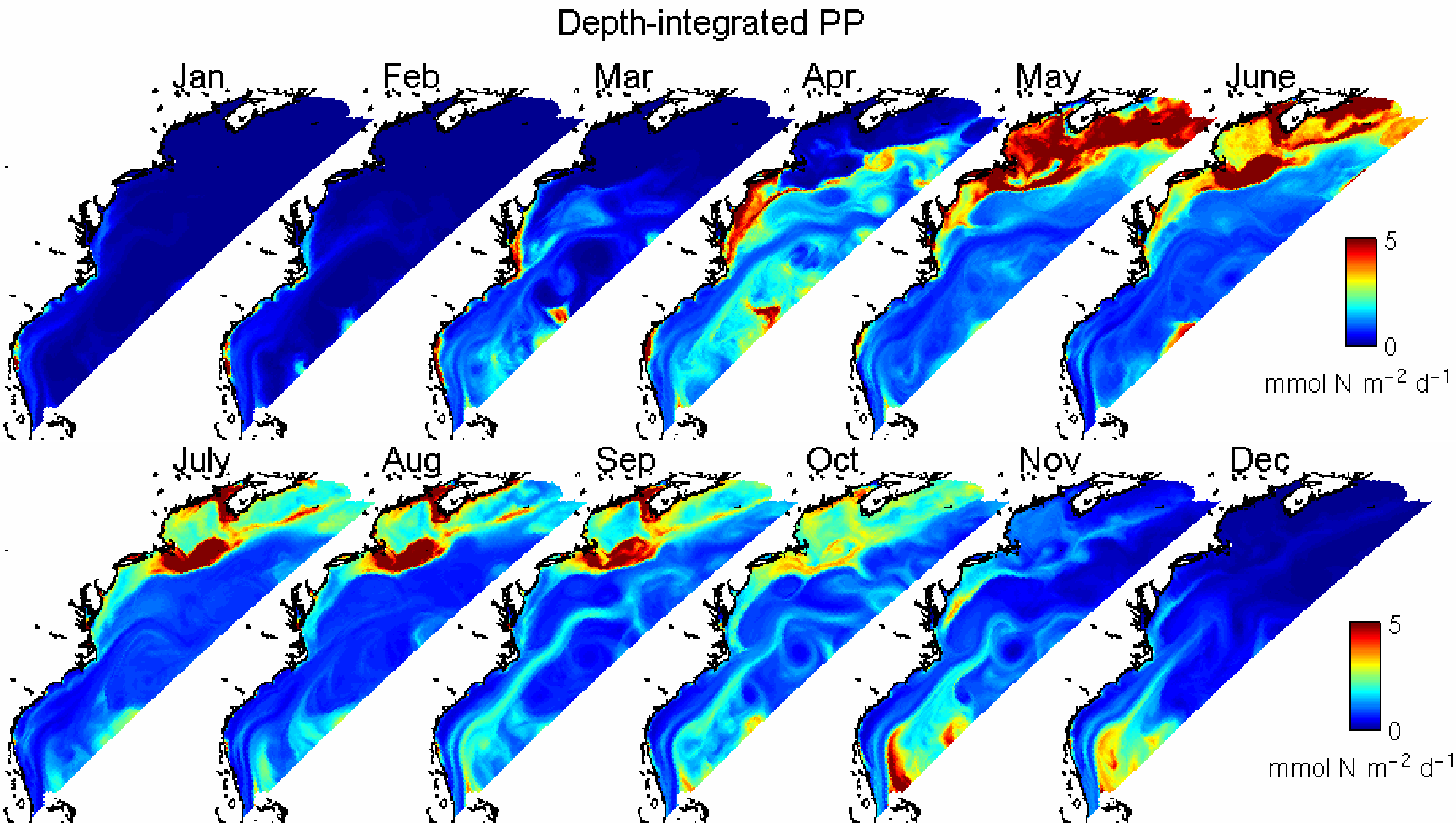


Upper and lower euphotic zone have very different turnover times (consistent with observations)!

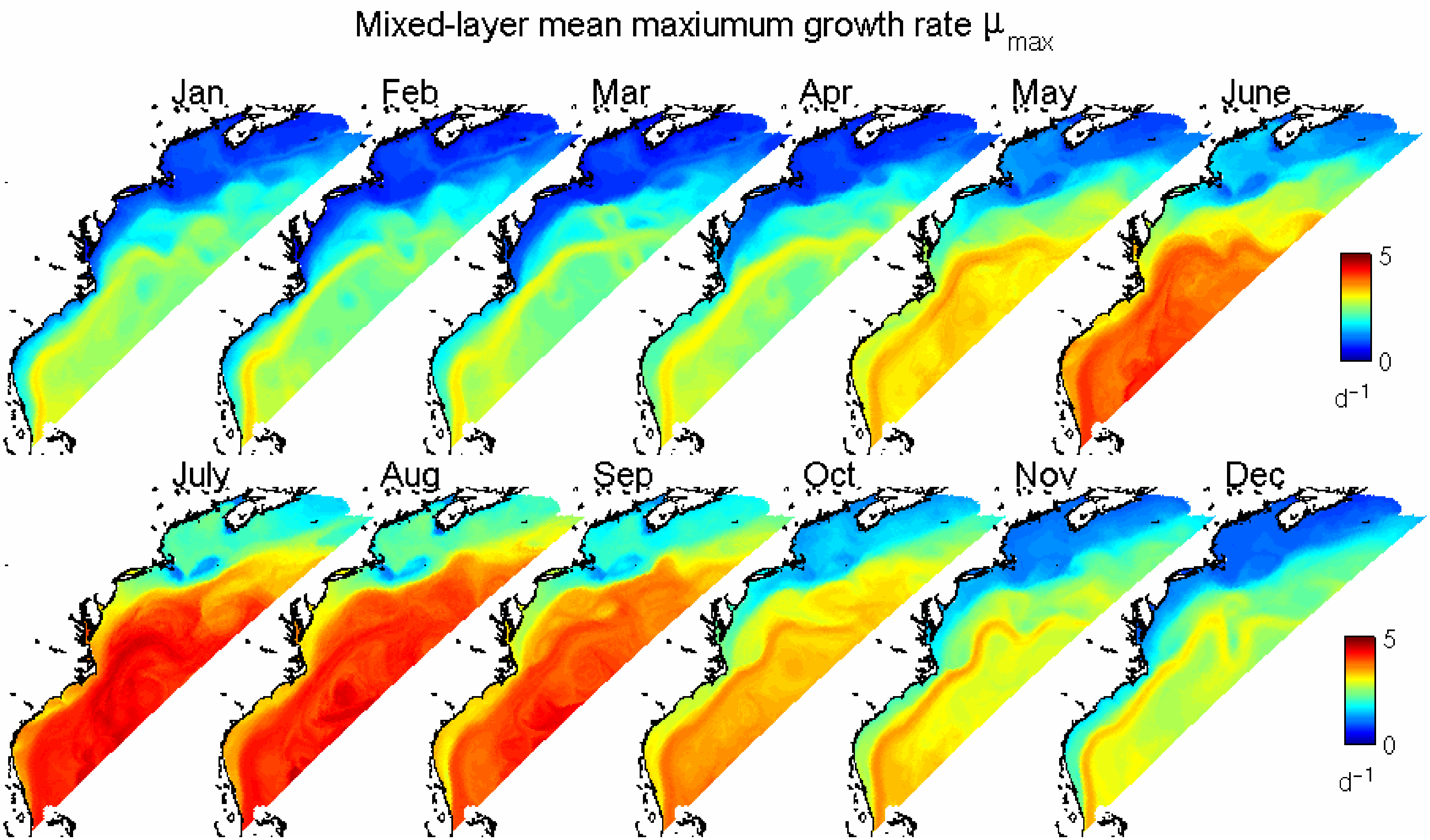
Summer observations for the MAB (Falkowski et al. 83): 4 ± 2 d (mixed layer)

14 ± 12 d (lower eu. Z.)

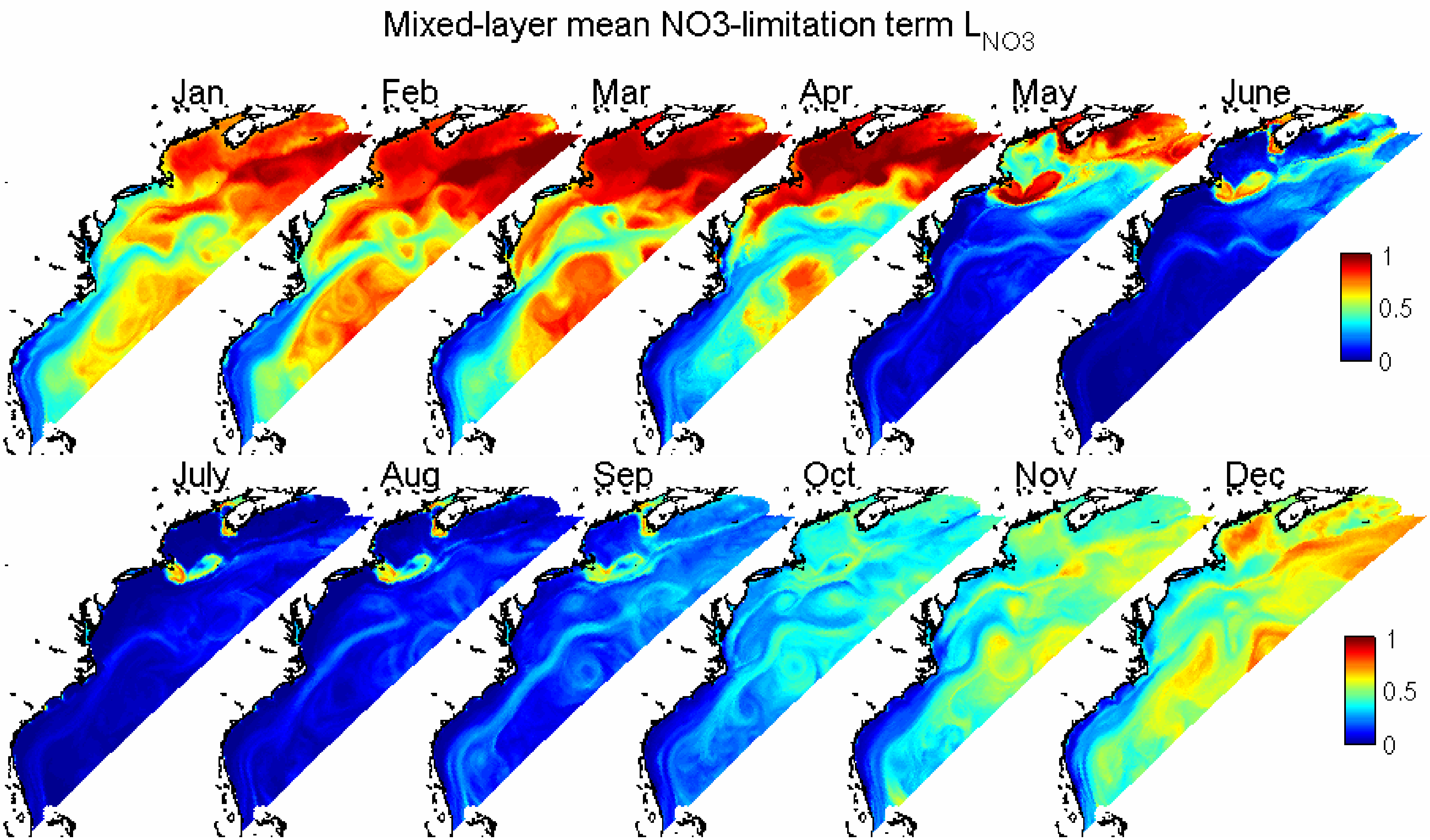

Lower euphotic turnover time
Jan
Feb
Mar
Apr
May
June
July
Aug
Sep
Oct
Nov
Dec
20
10
0
d
20
10
0
d


Depth-integrated PP
Jan
Feb
Mar
Apr
May
June
July
Aug
Sep
Oct
Nov
Dec
5
0
mmol N m-2 d-1
5
0
mmol N m-2 d-1

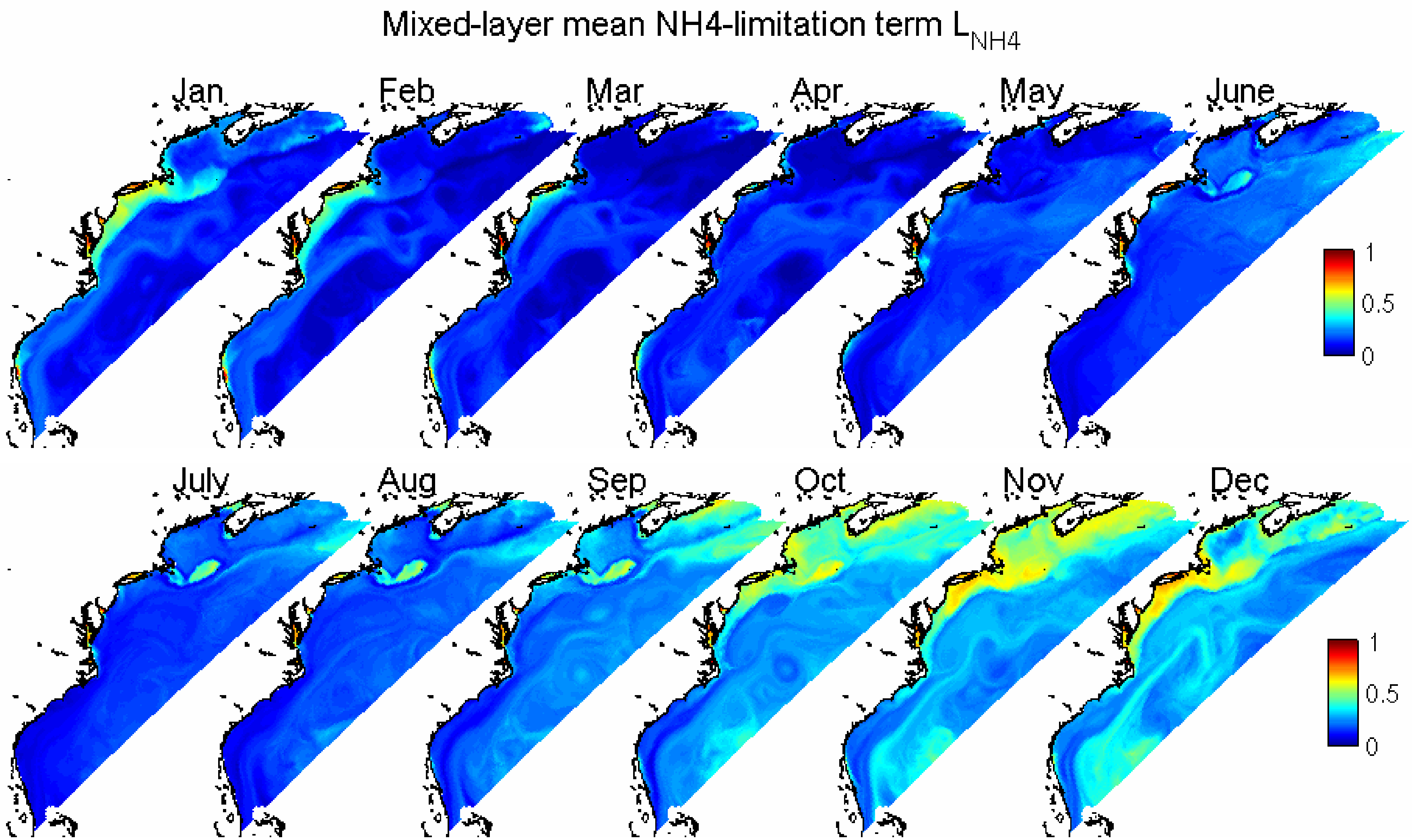
Assessing relative contributions from the different limitation terms



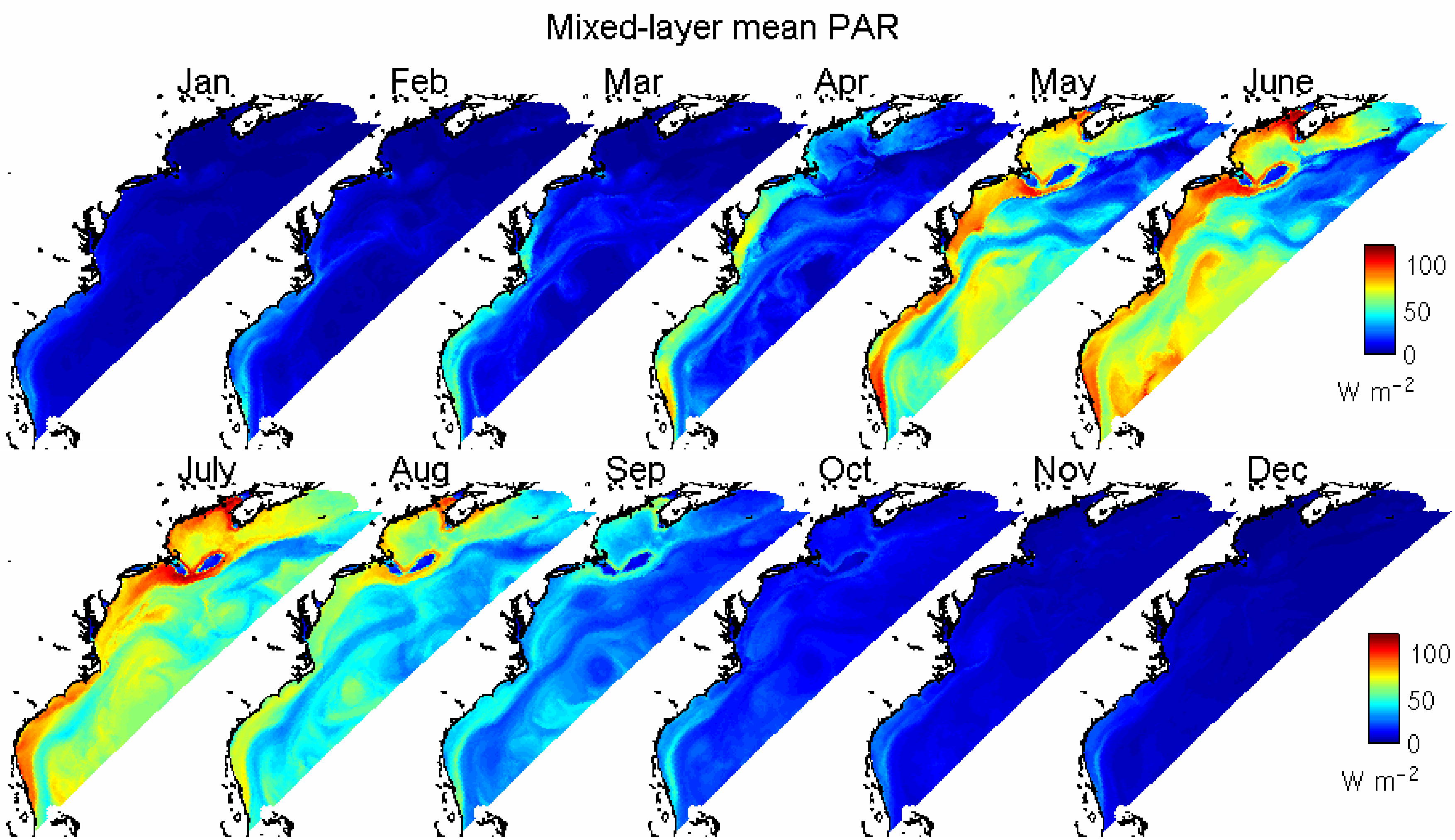
Mixed-layer mean maxiumum growth rate μ max
Jan
Feb
Mar
Apr
May
June
July
Aug
Sep
Oct
Nov
Dec
5
0
d-1
5
0
d-1

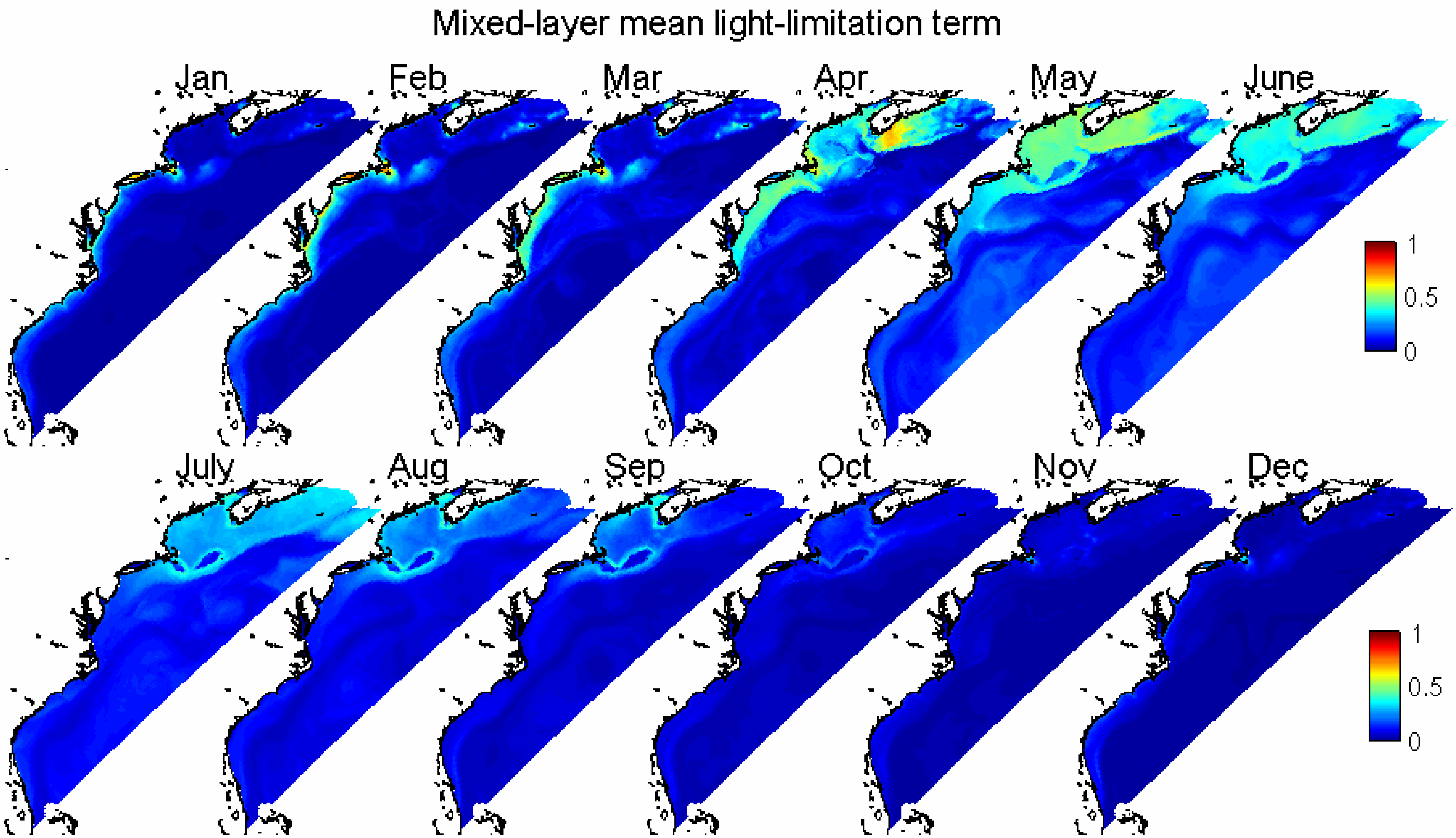


Limitation term can vary between 0 and 1.
1 means no limitation.
Small values mean strong limitation.



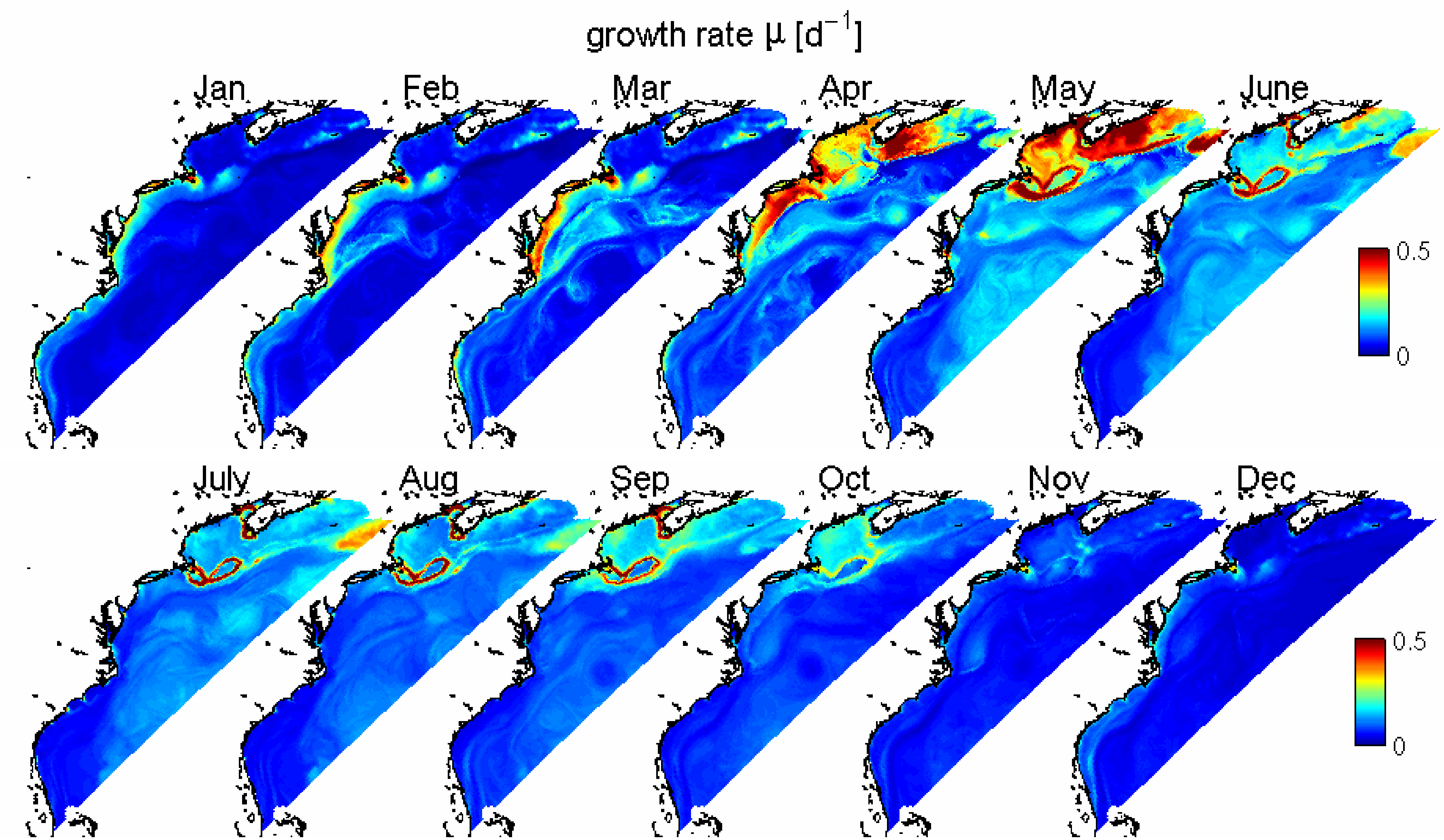
Mixed-layer mean NH4-limitation term L
NH4
Jan
Feb
Mar
Apr
May
June
July
Aug
Sep
Oct
Nov
Dec
1
0.5
0
1
0.5
0


Mixed-layer mean PAR
Jan
Feb
Mar
Apr
May
June
100
50
0
W m-2
July
Aug
Sep
Oct
Nov
Dec
100
50
0
W m-2

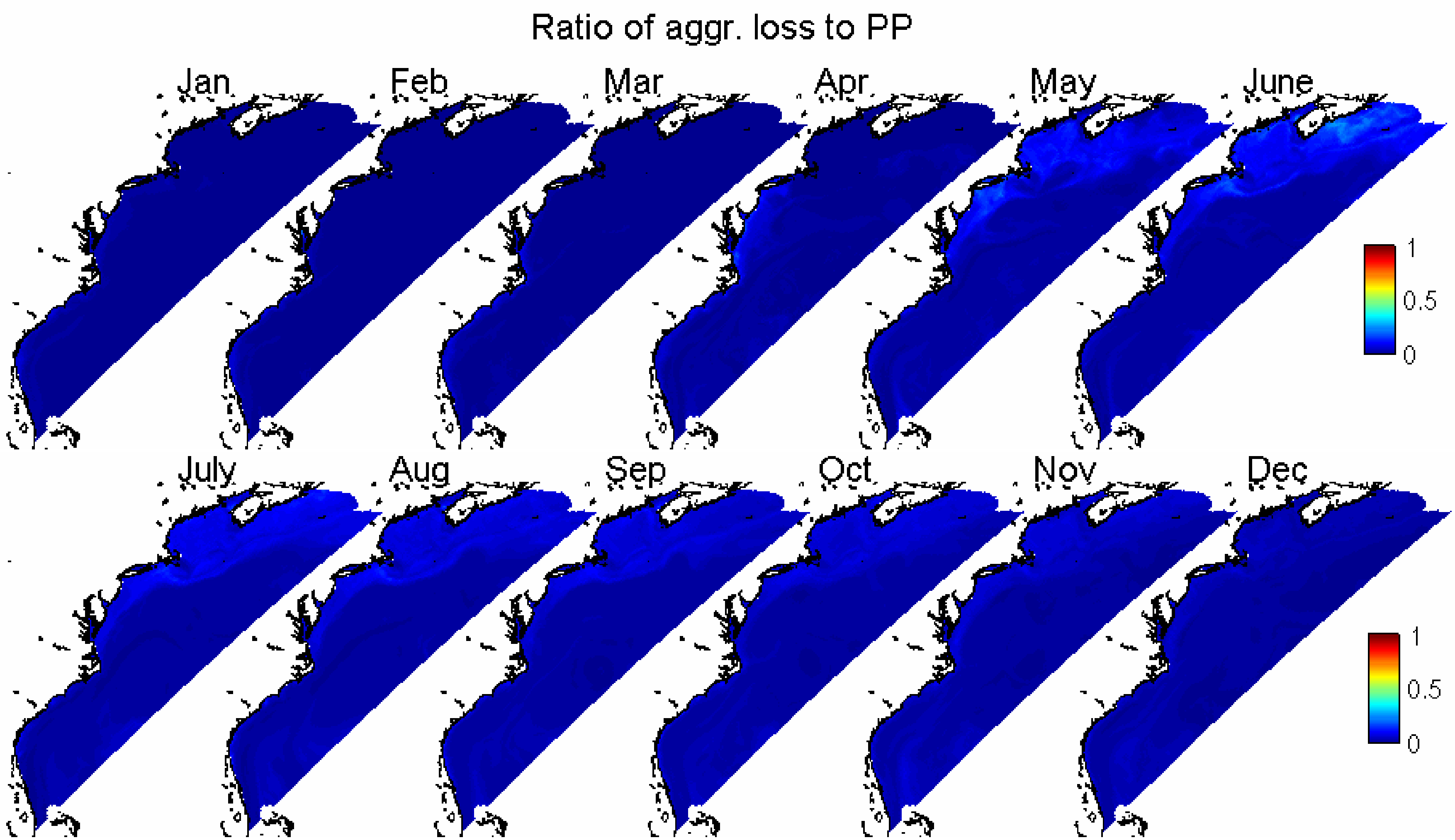


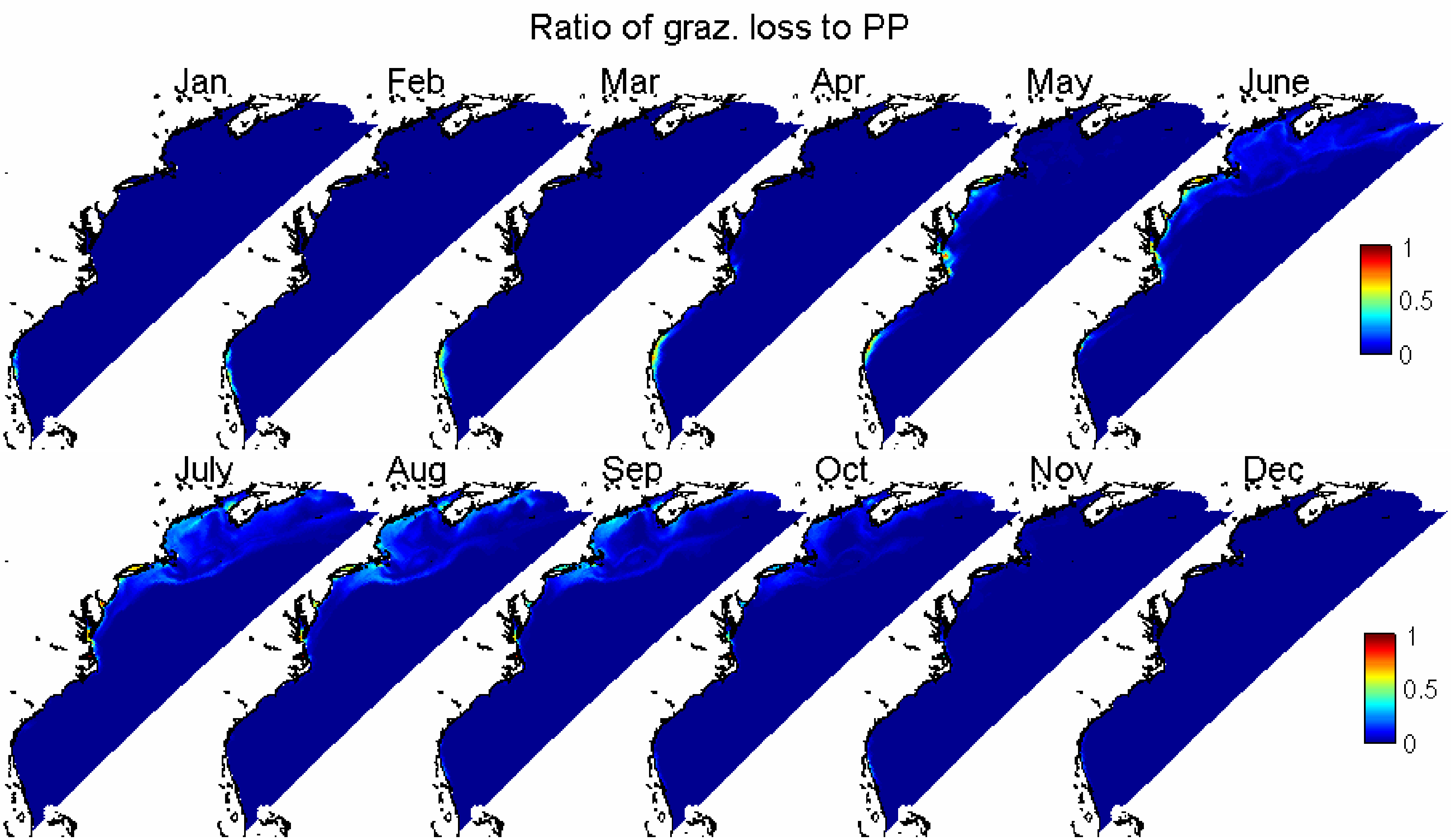
Limitation term can vary between 0 and 1.
1 means no limitation.
Small values mean strong limitation.

Light-limitation appears too strong.
α=0.025 molC/mg chl (W m^{-2})$^{-1}$ d^{-1}
At the lower end of the range. Compare e.g. w/ Lima and Doney's α=0.25 (same units)

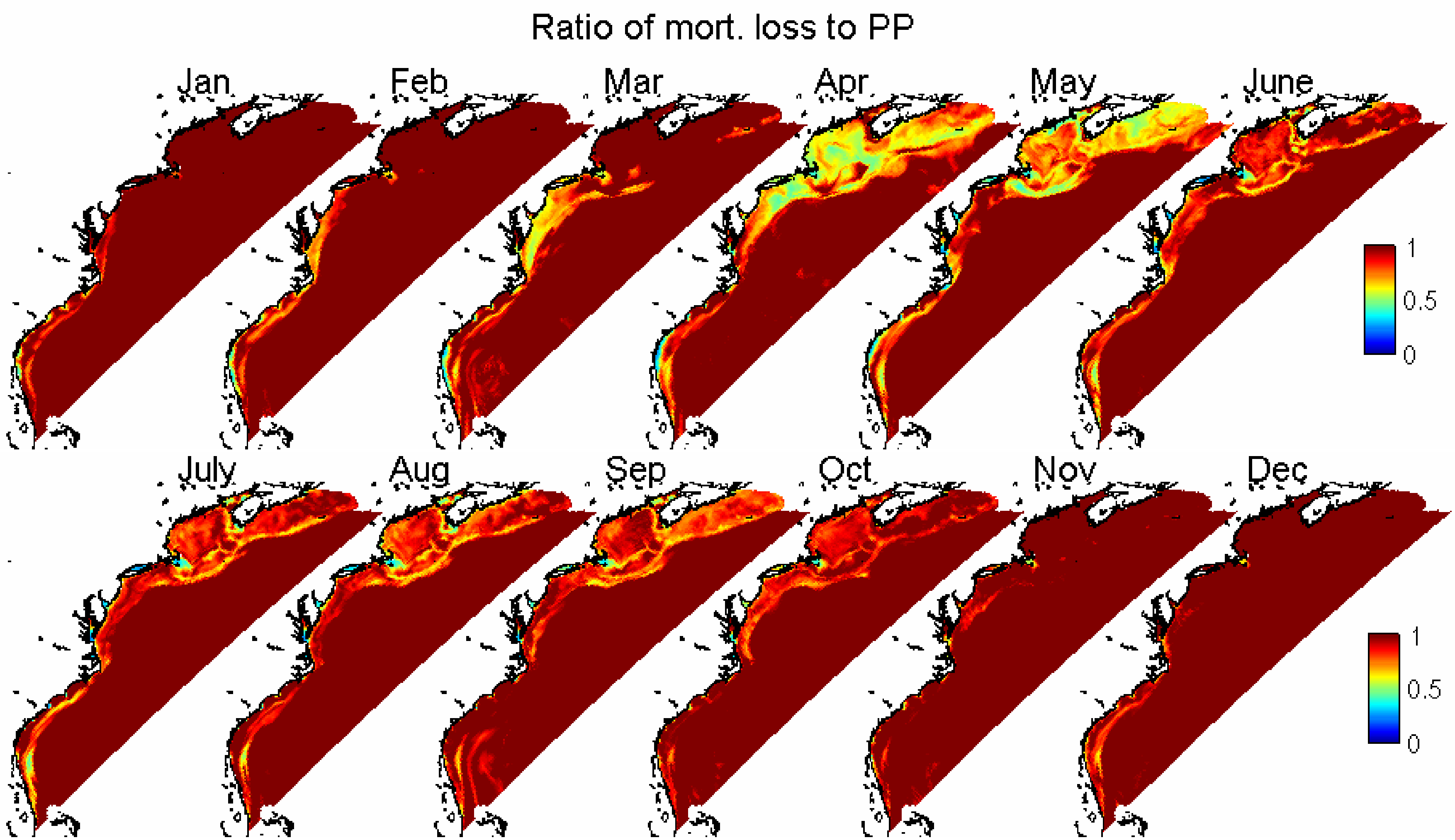

growth rate μ [d⁻¹]
Jan
Feb
Mar
Apr
May
June
0.5
0
July
Aug
Sep
Oct
Nov
Dec
0.5
0

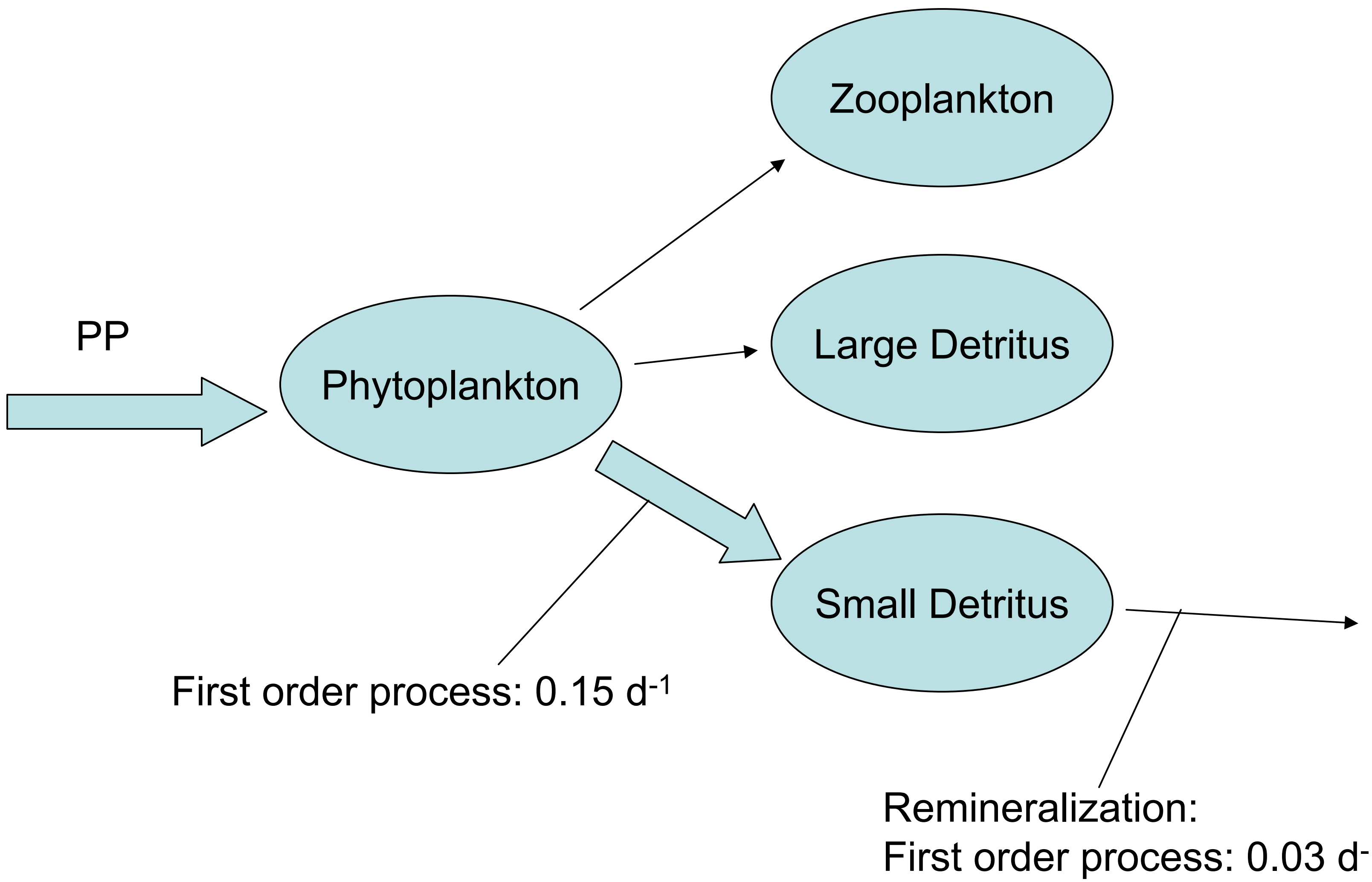
Assessing phytoplankton source versus sinks terms


Ratio of aggr. loss to PP
Jan
Feb
Mar
Apr
May
June
July
Aug
Sep
Oct
Nov
Dec
1
0.5
0
1
0.5
0



Ratio of graz. loss to PP
Jan
Feb
Mar
Apr
May
June
July
Aug
Sep
Oct
Nov
Dec
1
0.5
0
1
0.5
0


Ratio of mort. loss to PP
Jan
Feb
Mar
Apr
May
June
July
Aug
Sep
Oct
Nov
Dec
1
0.5
0
1
0.5
0


PP
Phytoplankton
Zooplankton
Large Detritus
Small Detritus
First order process: 0.15 d-1
Remineralization:
First order process: 0.03 d-1

Next steps:

- k_{CDOM} too high in Gulf of Maine and on the Scotian Shelf (low salinity there is indicative of Labrador Seawater, not so much estuarine water)
  - Short-term: introduce latitudinal dependence
  - Longer-term: use Antonio's k_{CDOM}
- Model parameters need tuning (use 1D models in various strategic locations):
  - Light-limitation appears too strong
  - Relative importance of different phytoplankton loss terms appears "out of balance"

Conclusions

- Diagnostics useful
- They make some of the dynamics more transparent
- Elucidated some trouble areas
- Ultimately may give us new insight into biological dynamics

End

Table 1. Mean, range, number of data points (N), and standard error (SE) for coastal and open ocean data of integrated phytoplankton biomass (AutoB, mg C m^{-2}), bacterial biomass (BB, mg C m^{-2}), protozooplankton biomass (ProtB, mg C m^{-2}), mesozooplankton biomass (ZooB, mg C m^{-2}), total heterotrophic biomass (HB, mg C m^{-2}), chlorophyll concentration (Chl, mg m^{-2}), phytoplankton production (PP, mg C m^{-2} d^{-1}), phytoplaknton-specific production [P_B, mg C mg C^{-1} d^{-1}], and the ratio of heterotrophic to autotrophic biomass (Ratio).

	Coastal			Open ocean		
	N	Mean±SE	Range	N	Mean±SE	Range
AutoB	163	2,921±335	52–31,860	279	1,966±126	22–17,500
BB	82	541±63	27–2,850	206	1,132±71	111–11,725
ProtB	86	313±39	6–1,952	119	489±116	3–13,475
ZooB	104	1,096±146	6–7,400	208	847±202	20–41,825
HB	70	1,535±196	136–8,260	138	2,521±479	413–67,025
Chl	82	78±13	5–637	130	67.4±7	2–438
PP	67	794±136	60–8,608	146	1,300±79	141–5,886
P_B	67	0.48±0.09	0.07–5.6	144	1.0±0.11	0.1–8.6
Ratio	70	0.98±0.10	0.05–3.2	122	1.85±0.16	0.17–10.2

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Biomass distribution in marine planktonic communities

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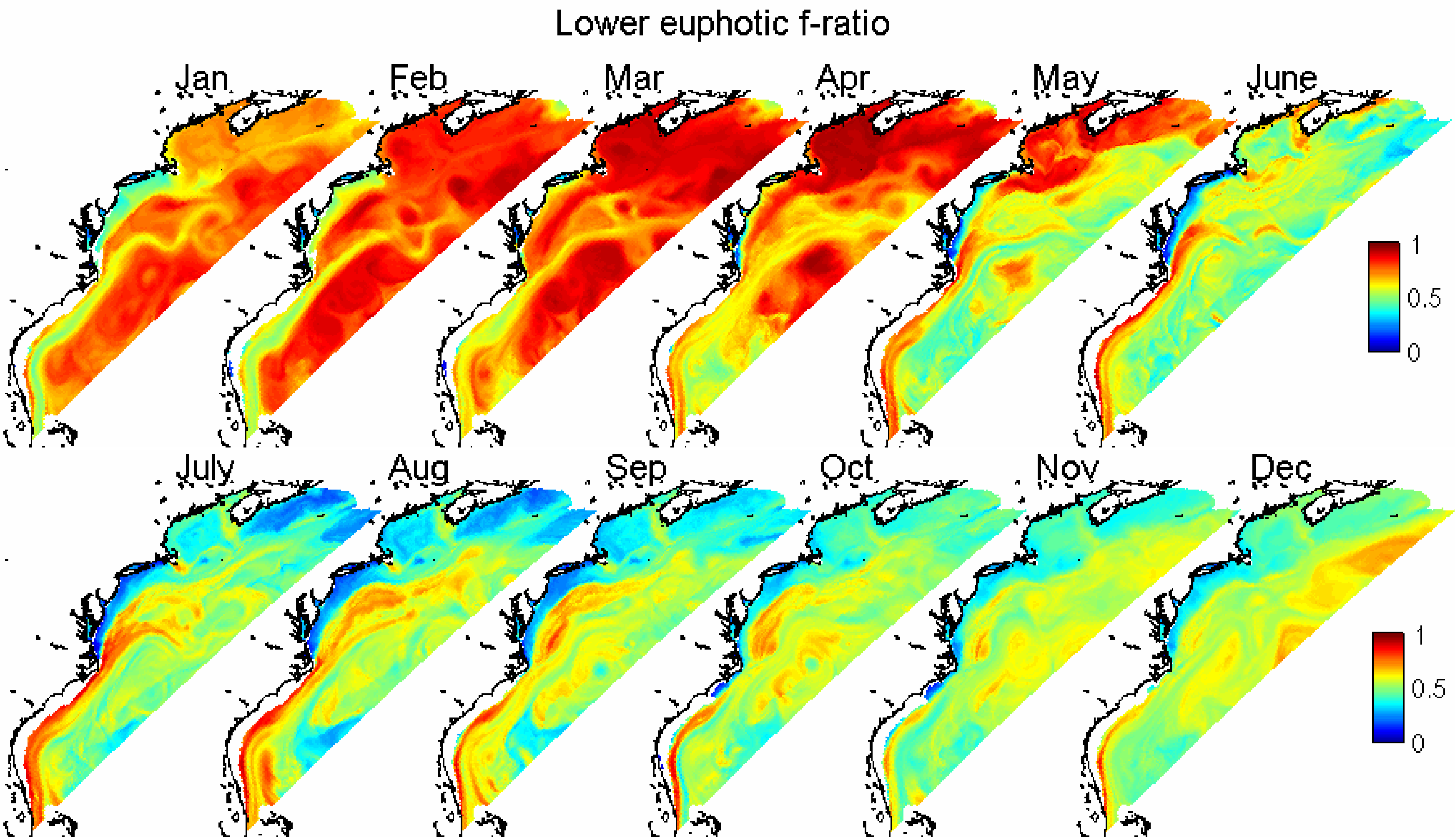

Replace by ratio of upper and lower!?