Modelling Denitrification

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Questions:

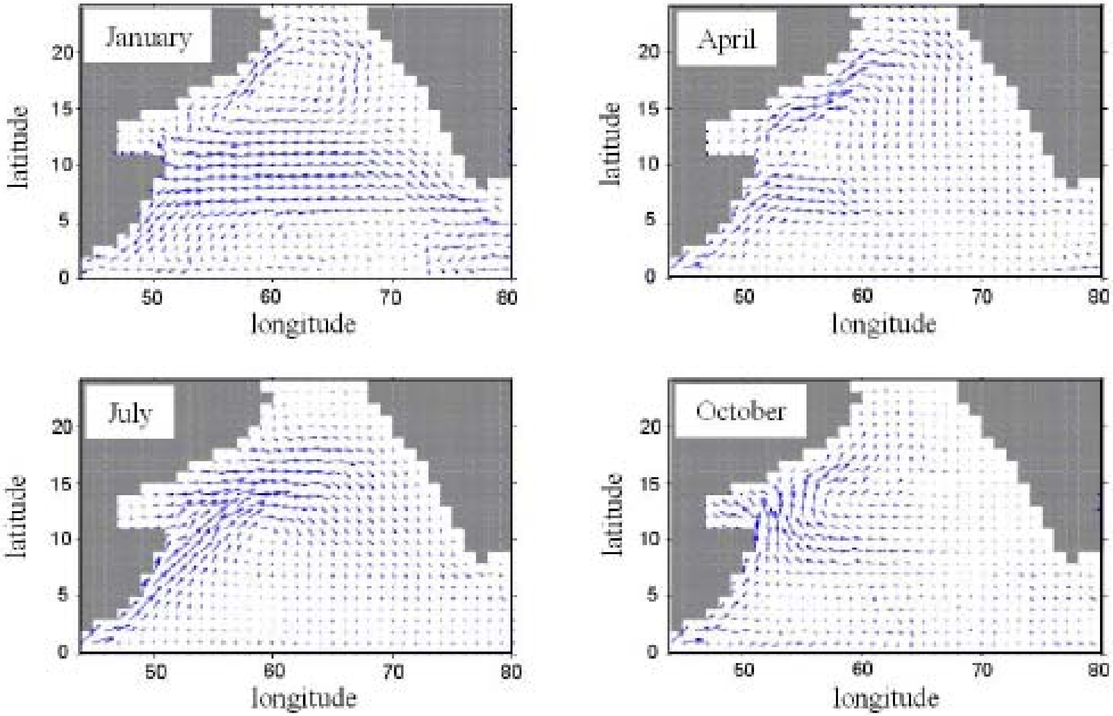
- Does denitrification occur in areas of highest primary production?
- Is lateral advection of organic matter important in fuelling denitrification?
- Does DOM contribute significantly to denitrification?
- Can bacterial carbon demand in the subeuphotic zone be reconciled with vertical supply by sinking detritus?

Physical model

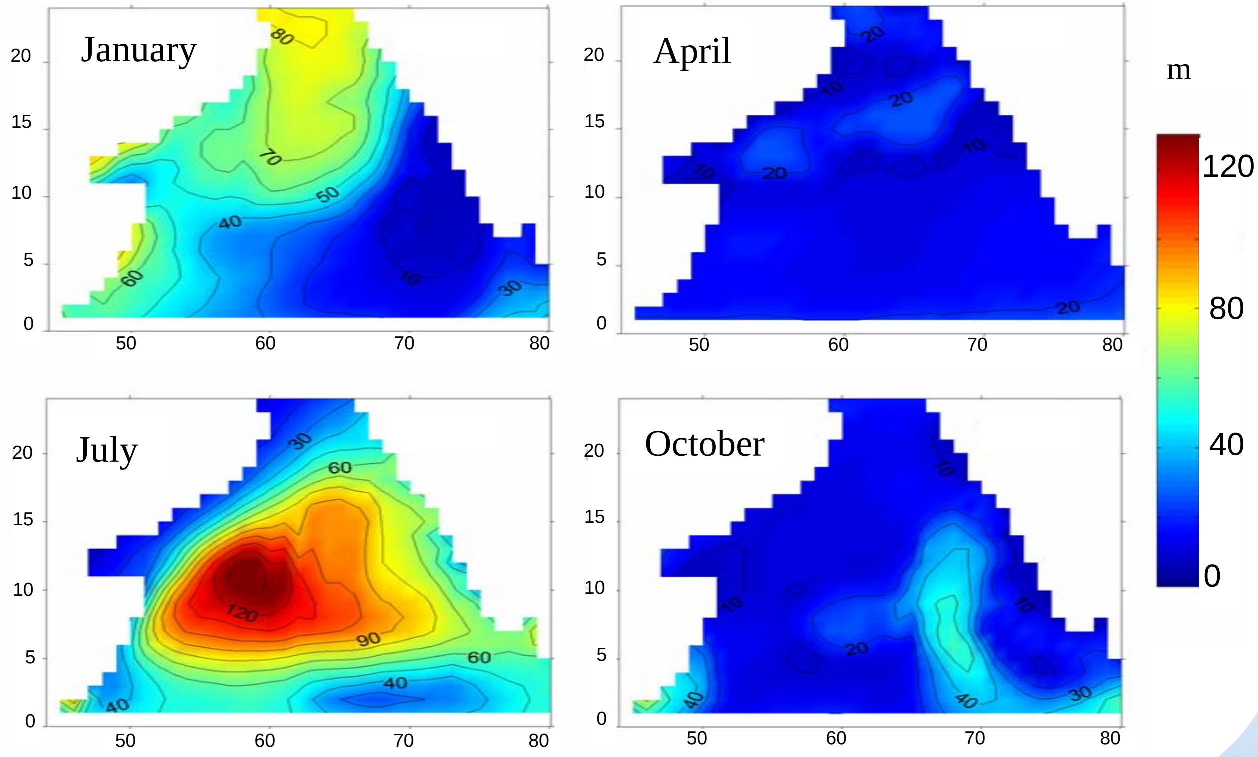
- 3D model of Gorchakov Ryabchenko et al. (1992):
- 33 levels
- 1 degree resolution with open southern boundary at 0.5ºS
- Kraus-Turner mixed layer
- Forced by mean monthly wind stress, plus heat and salt fluxes

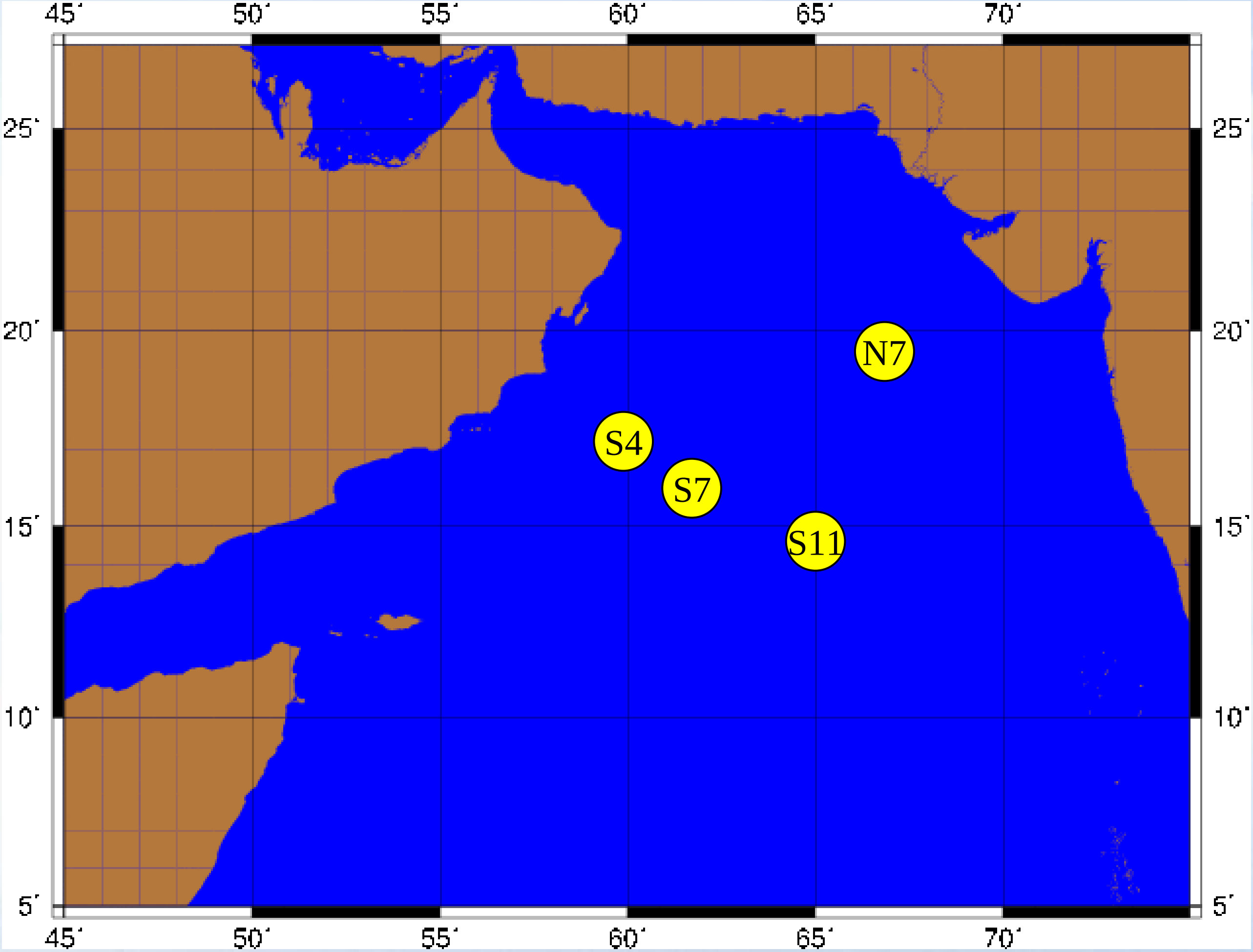
Gorchakov, V.A. and Ryabchenko, V.A. (1992). Okeanologiya 32, 203-210

Seasonal currents

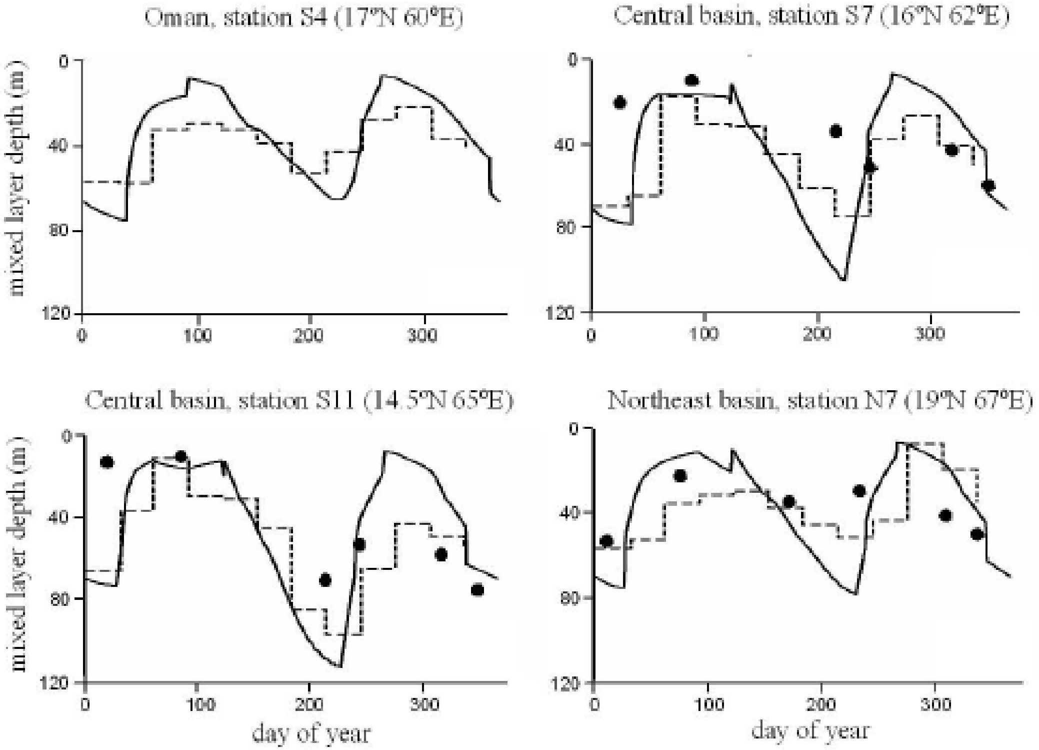


Predicted upper mixed layer depth

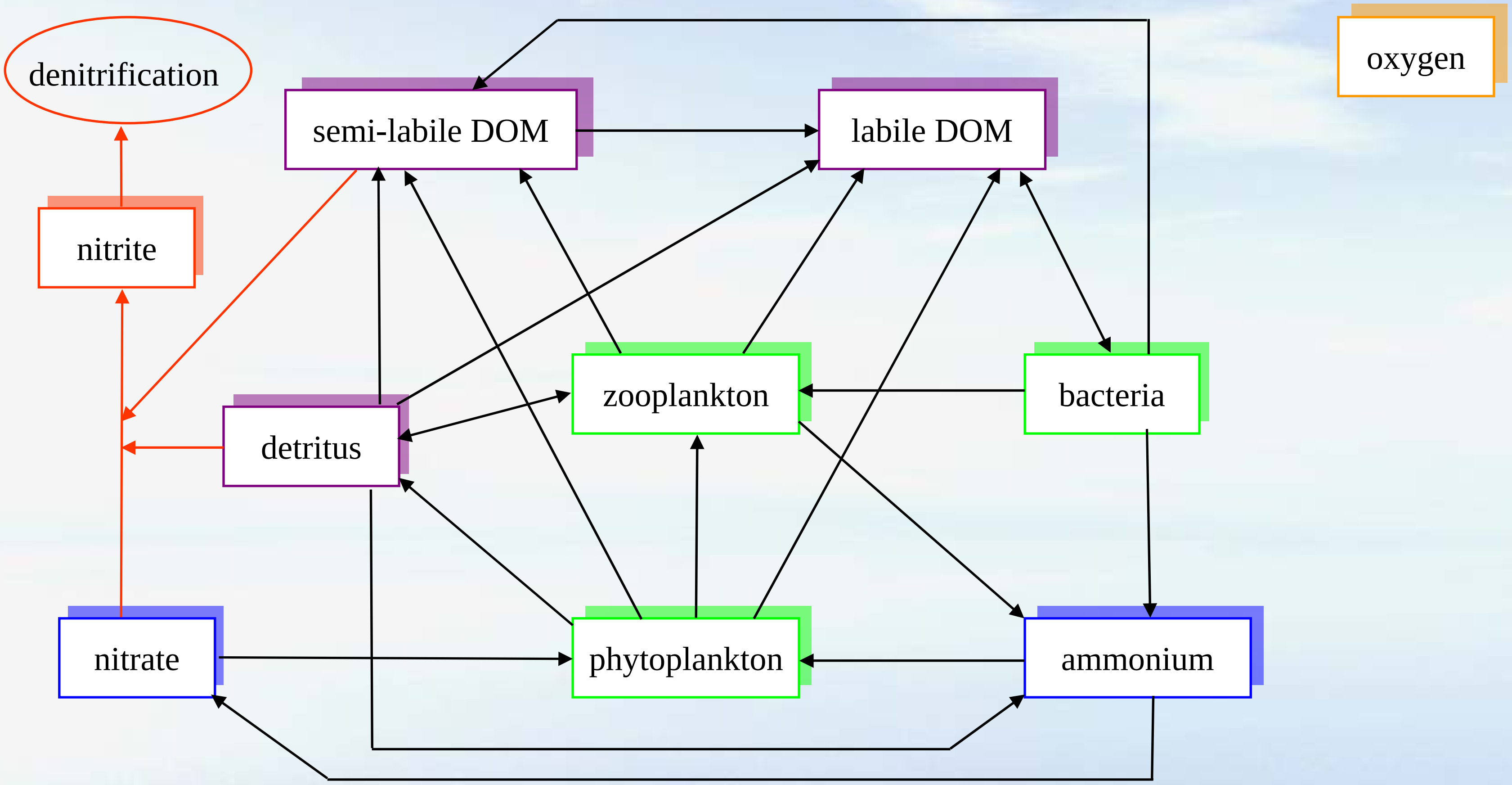



45˚
50˚
55˚
60˚
65˚
70˚
25˚
20˚
15˚
10˚
5˚
N7
S4
S7
S11

MLD: comparison with estimates from data



Ecosystem model



detritus sinking = 3 m d^{-1}

Denitrification

- Denitrification requires:

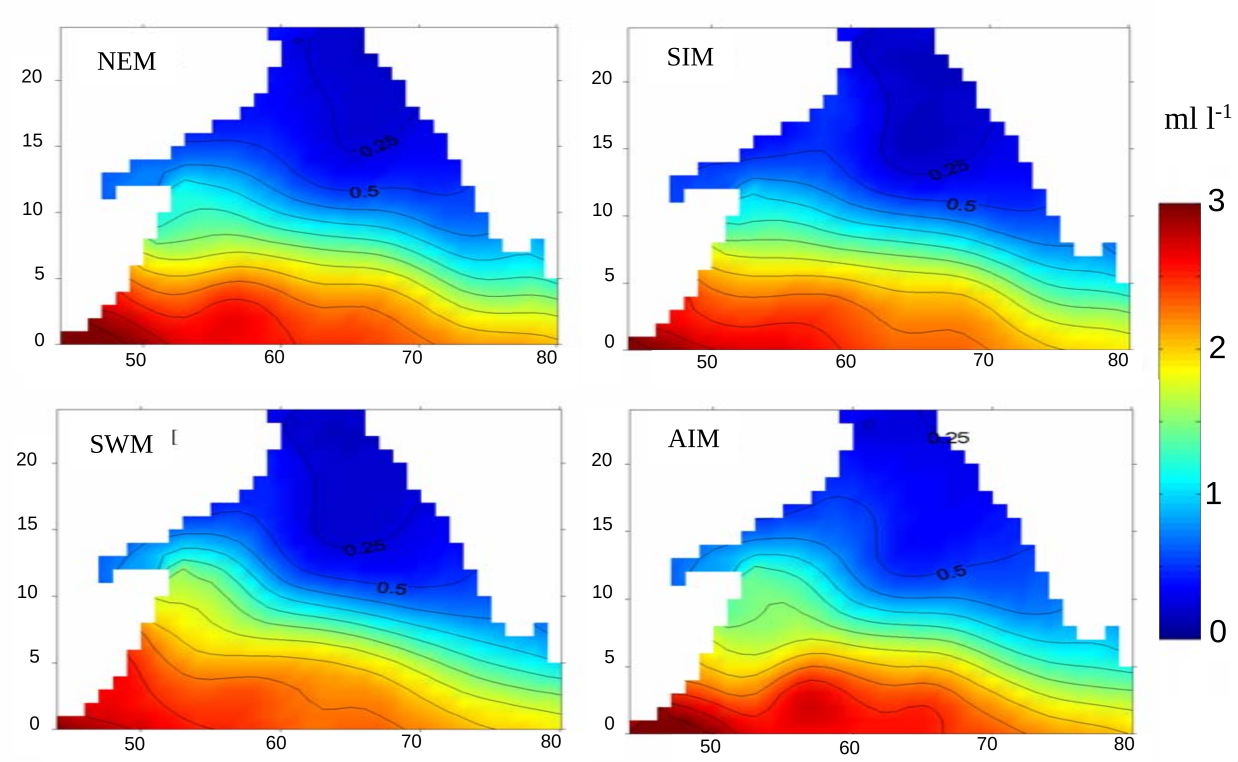
  nitrate and a source of organic matter

  low oxygen

- Stoichiometry of denitrification:

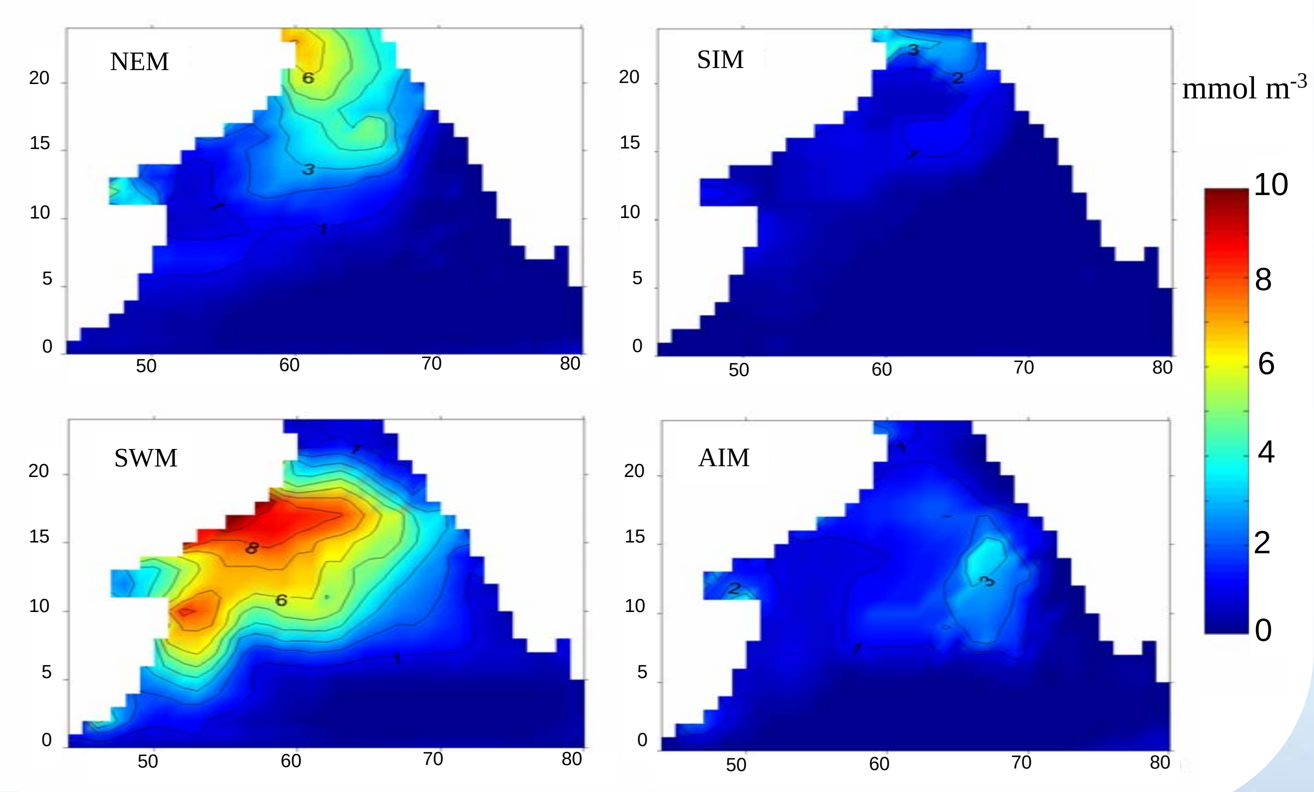
$$(CH_2O)_{106}(NH_3)_{16}(H_3PO_4) + 84.8HNO_3 \rightarrow 106CO_2 + 42.4N_2 + 148.4H_2O + 16NH_3 + H_3PO_4$$

Seasonal oxygen (z = 250 m)

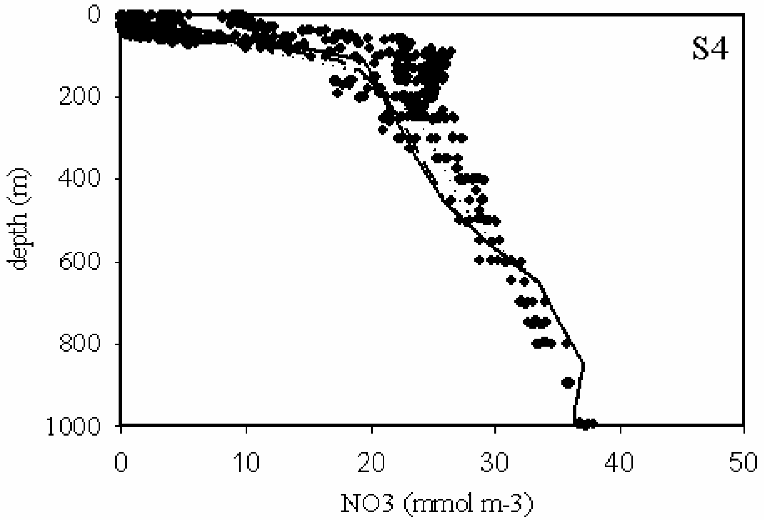


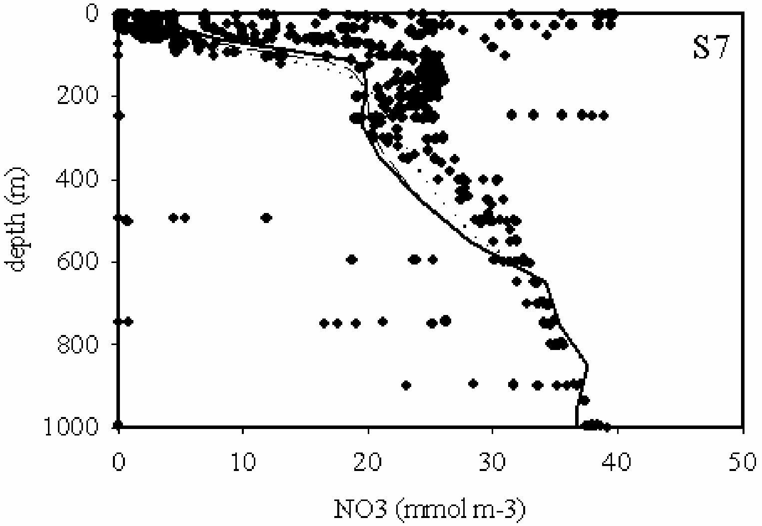
denitrification occurs when $O_2 < 0.25$ ml l^{-1}

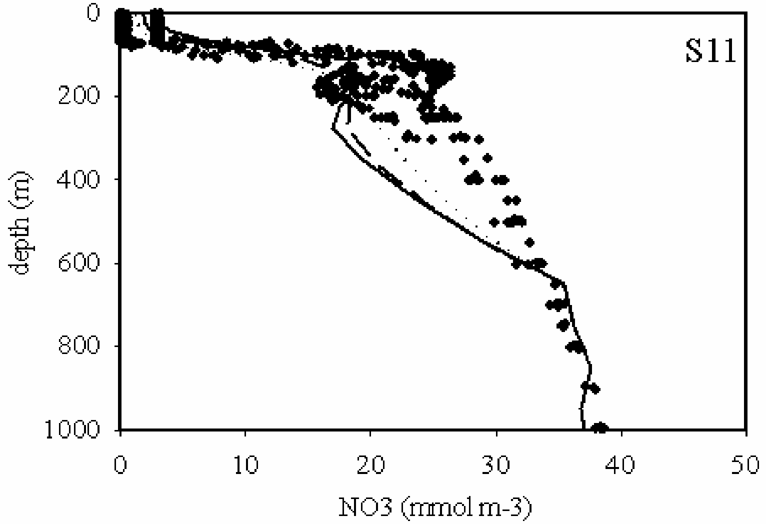
Seasonal nitrate (UML)

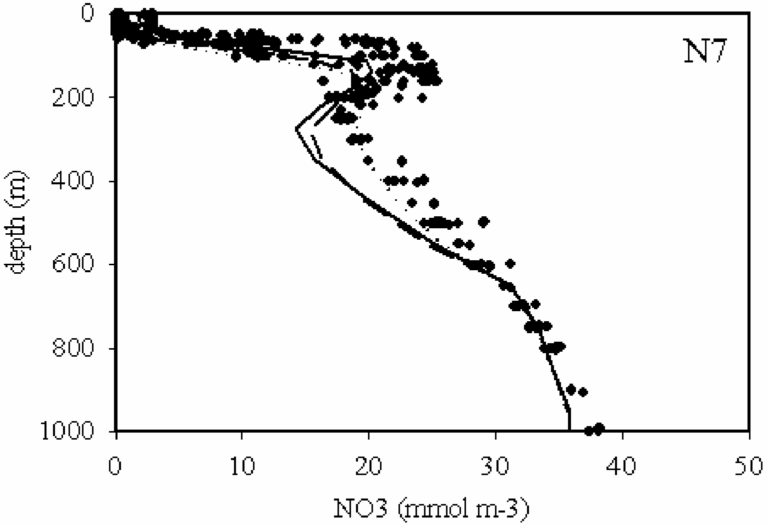


Nitrate profiles

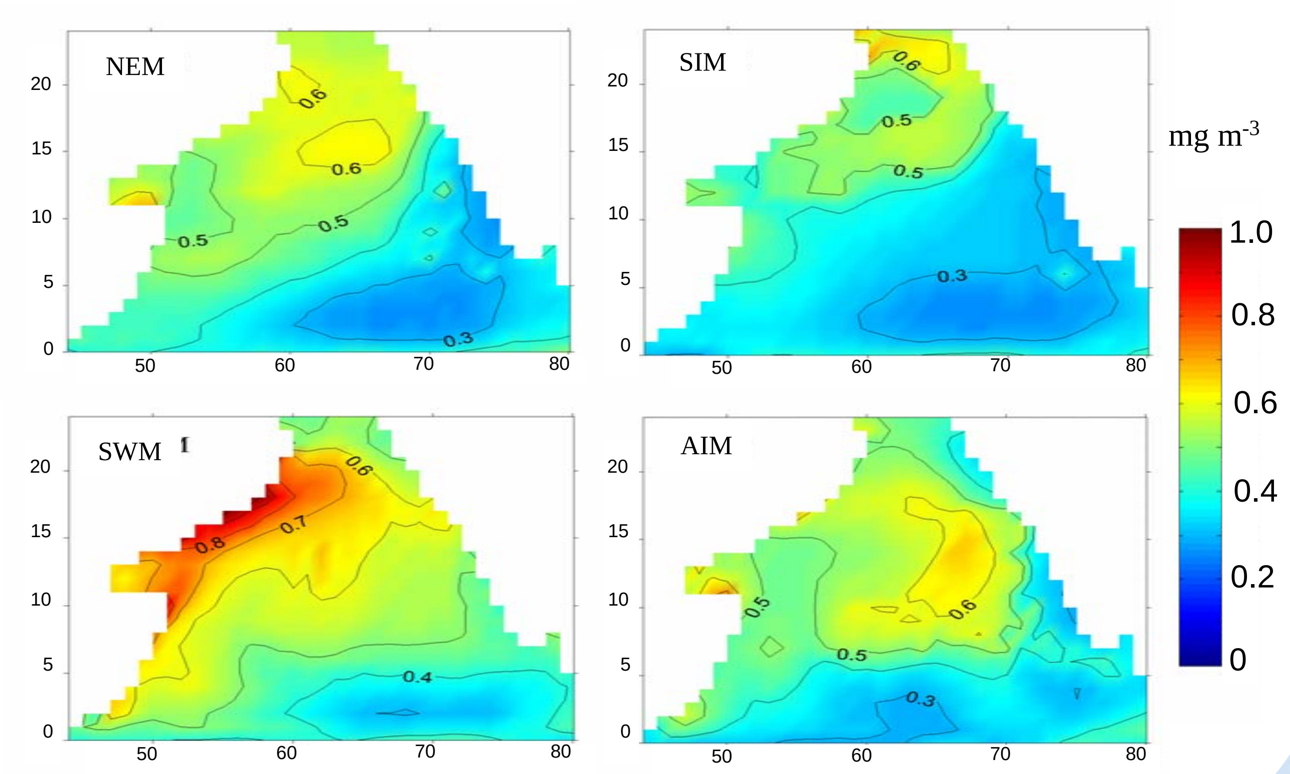




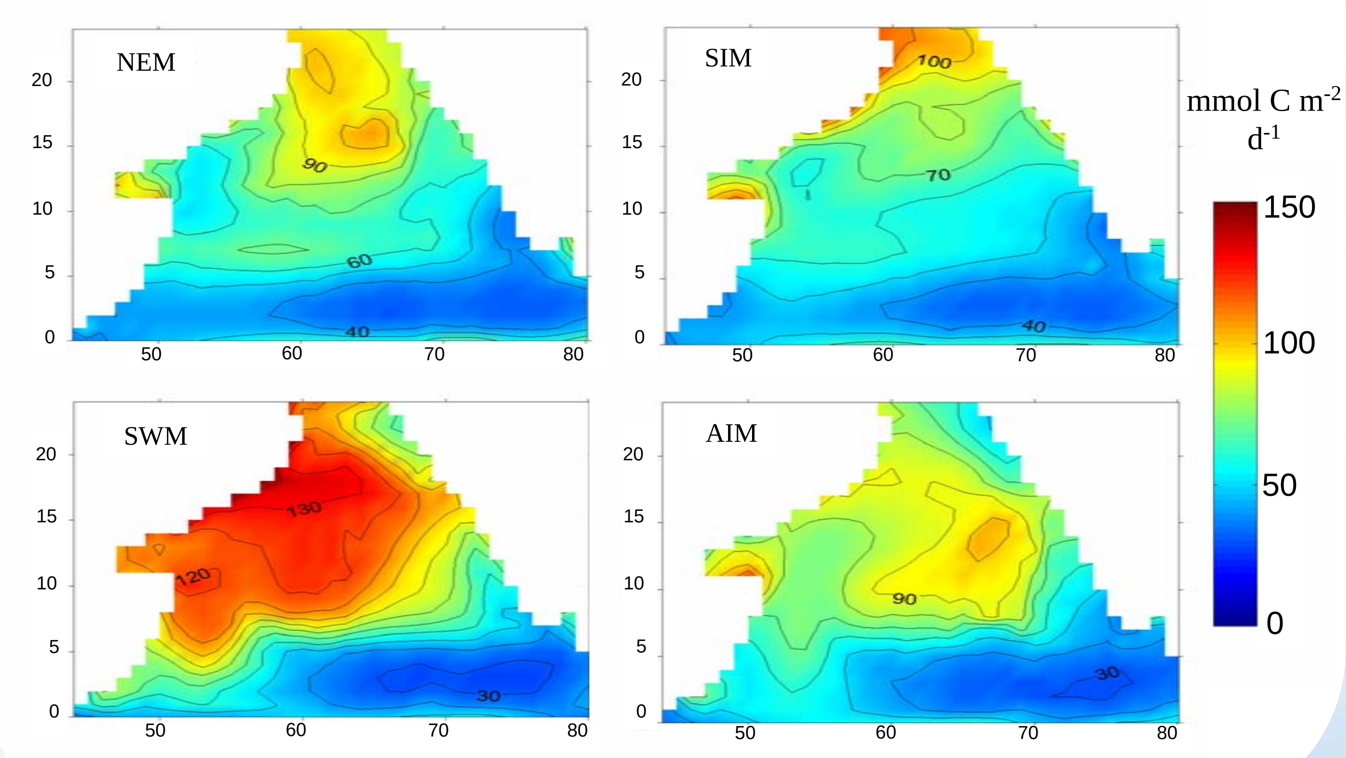




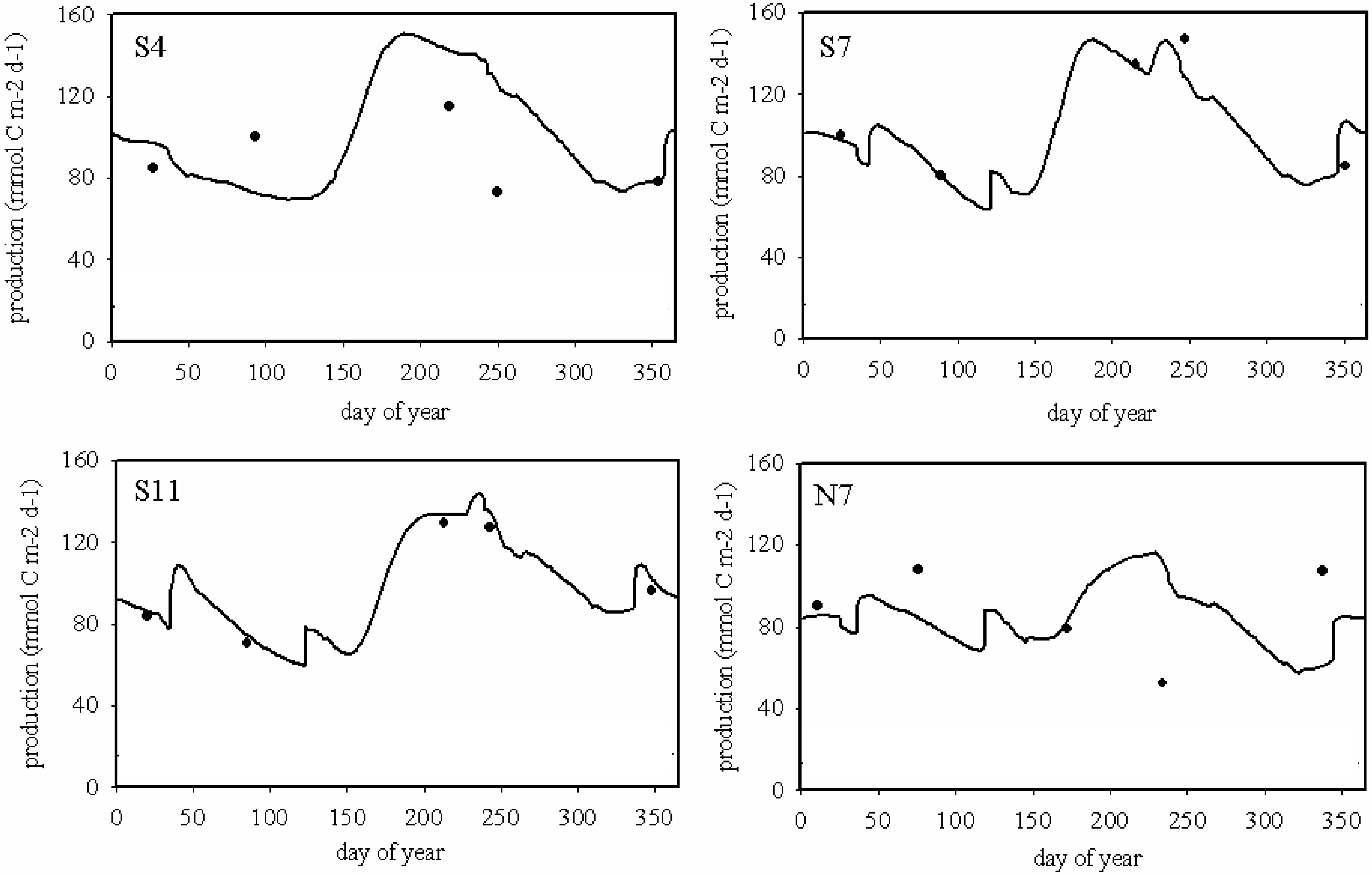
chlorophyll



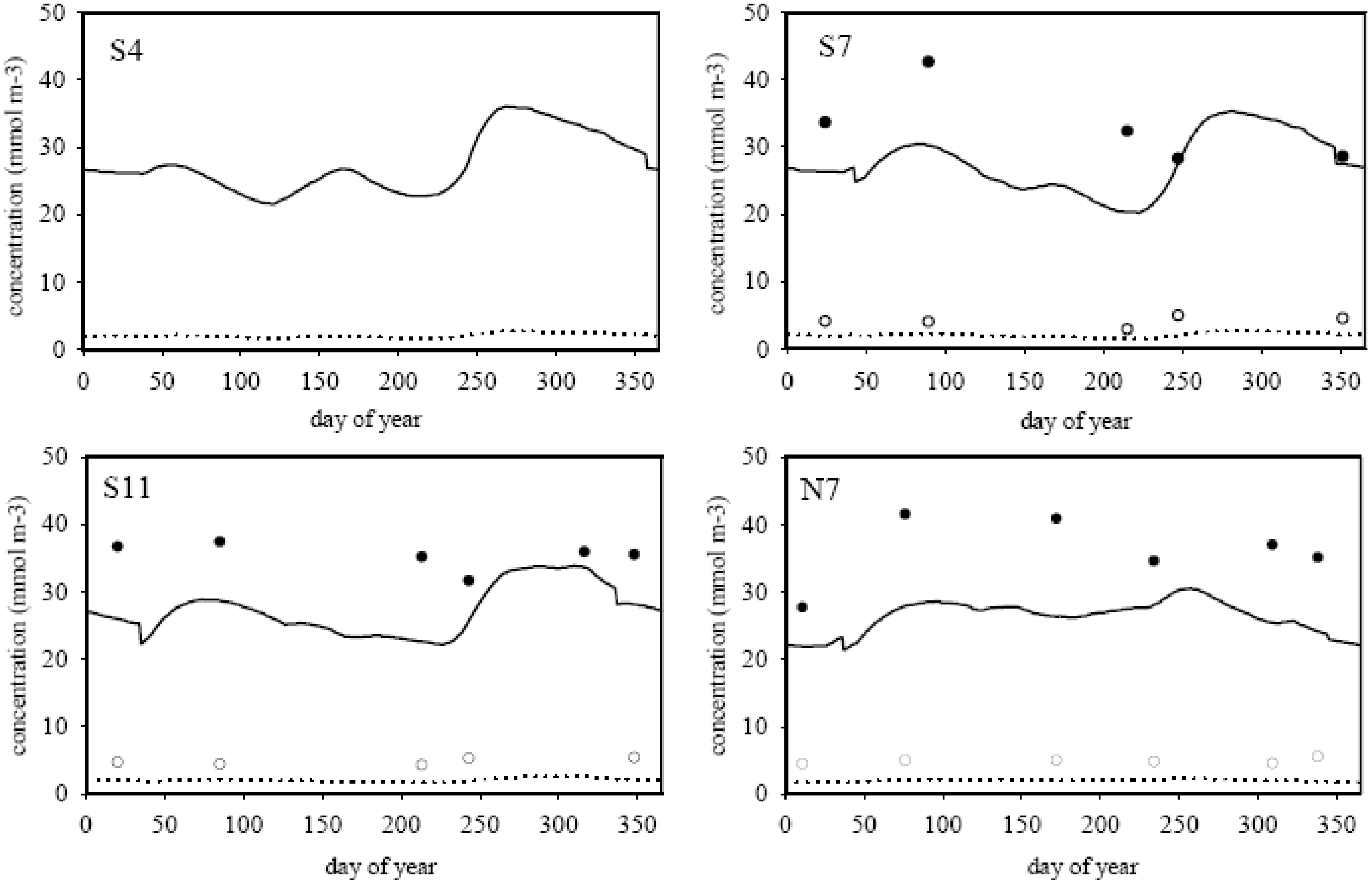
Primary production



Primary production

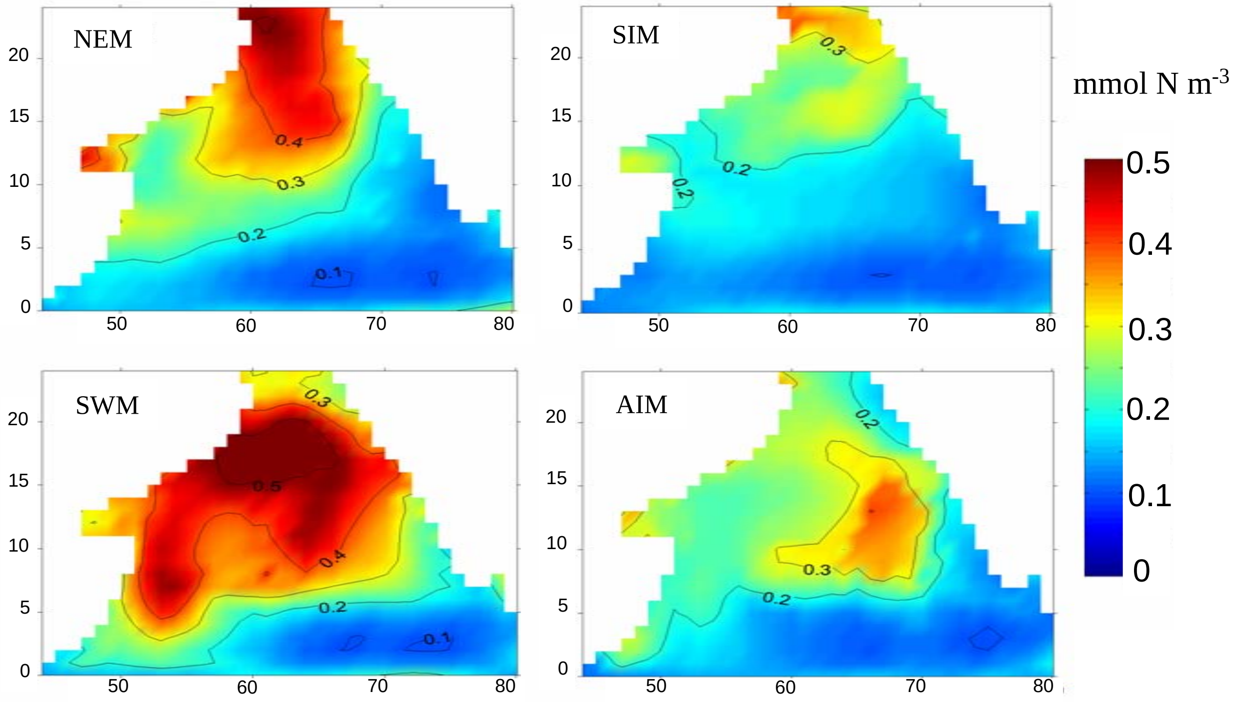


Dissolved organic matter

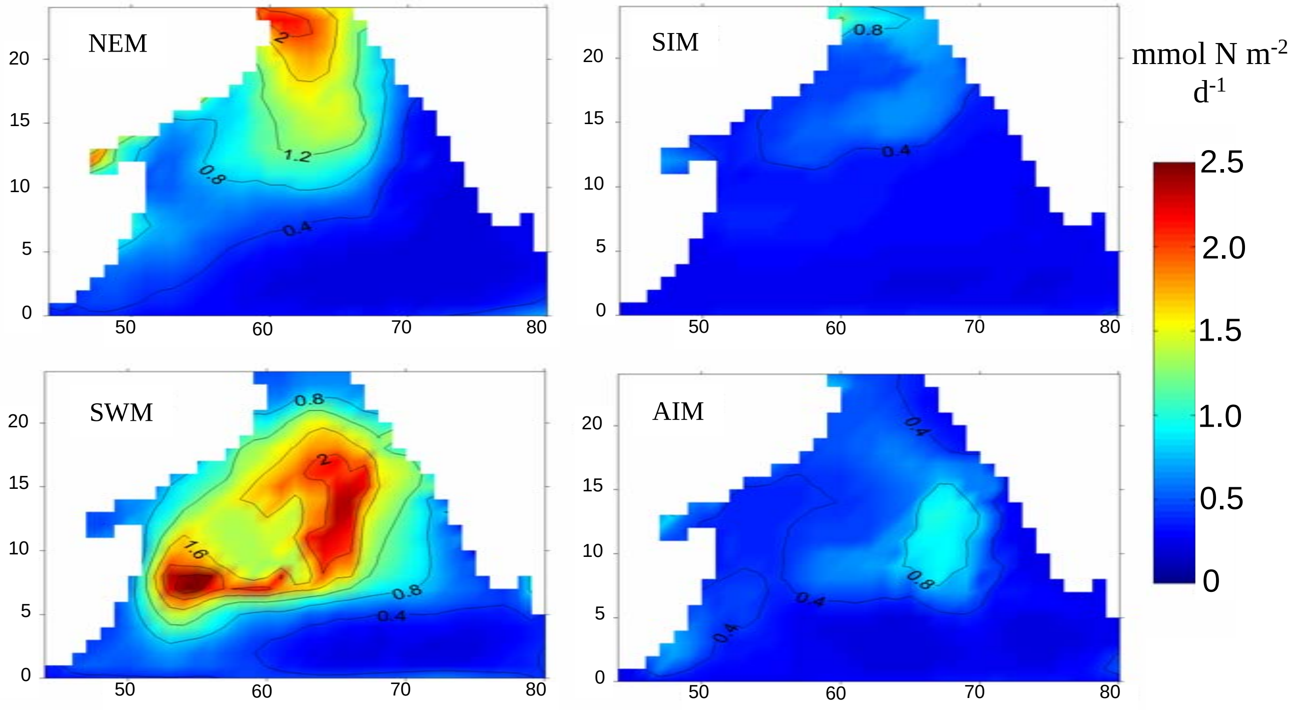


refractory baselines subtracted from data

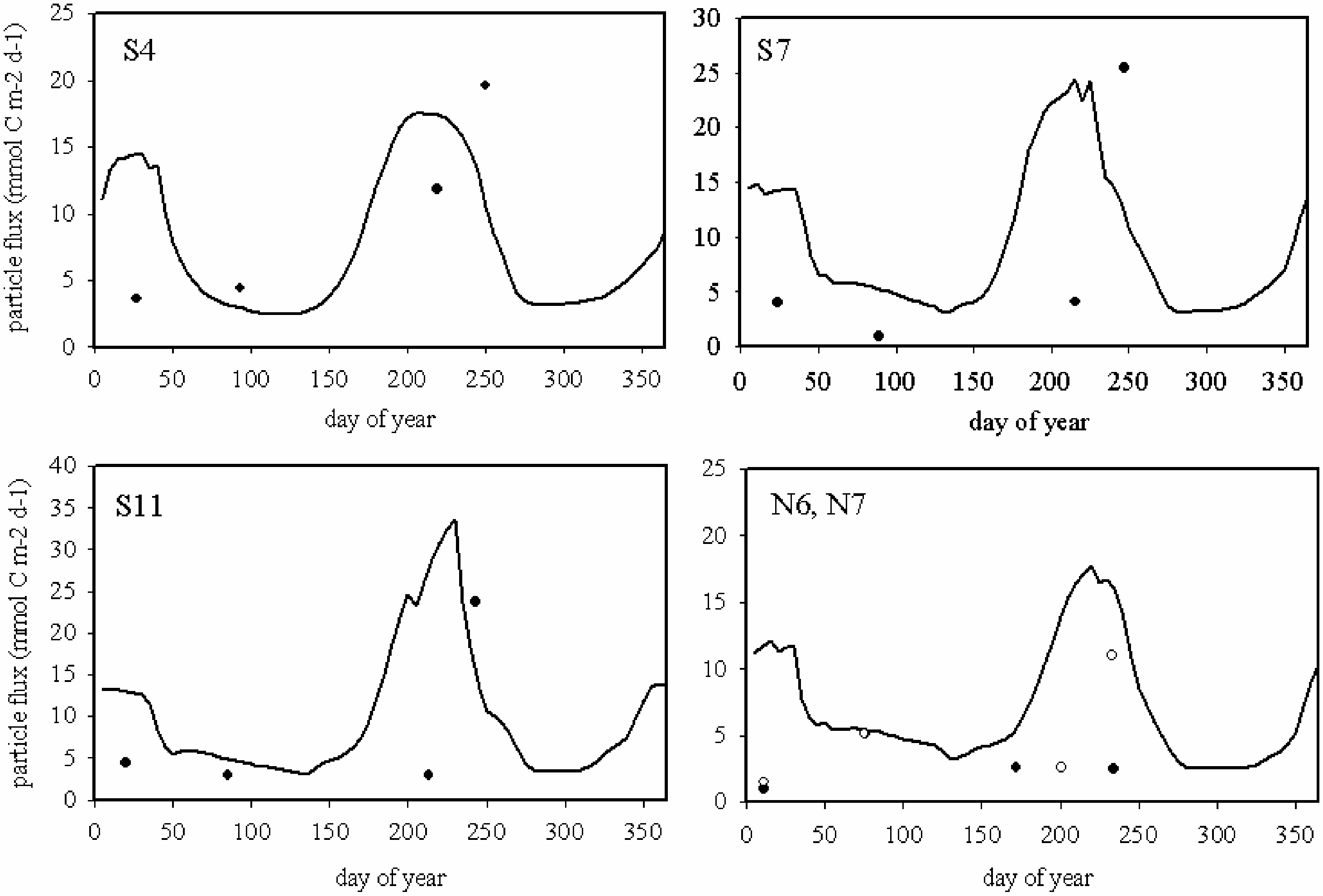
Detritus, 0-137 m



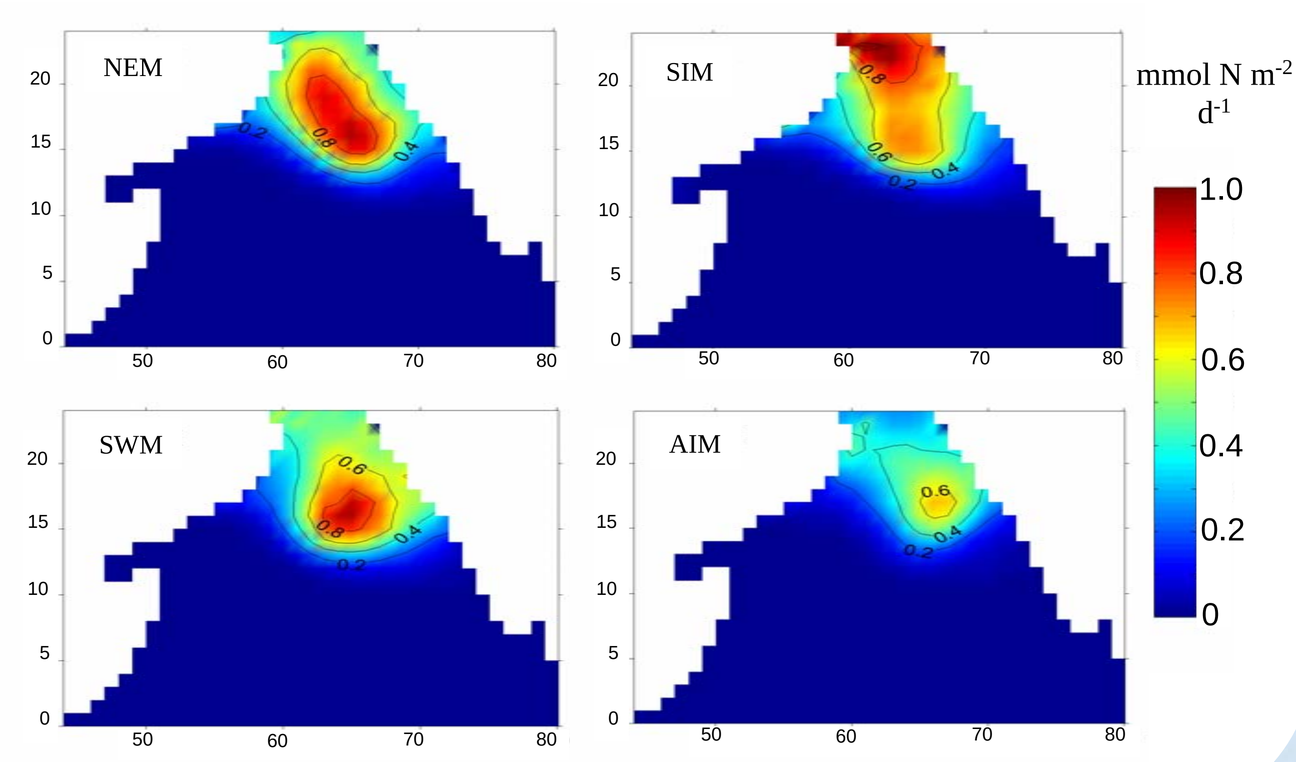
Detritus flux at 137 m



Particle flux



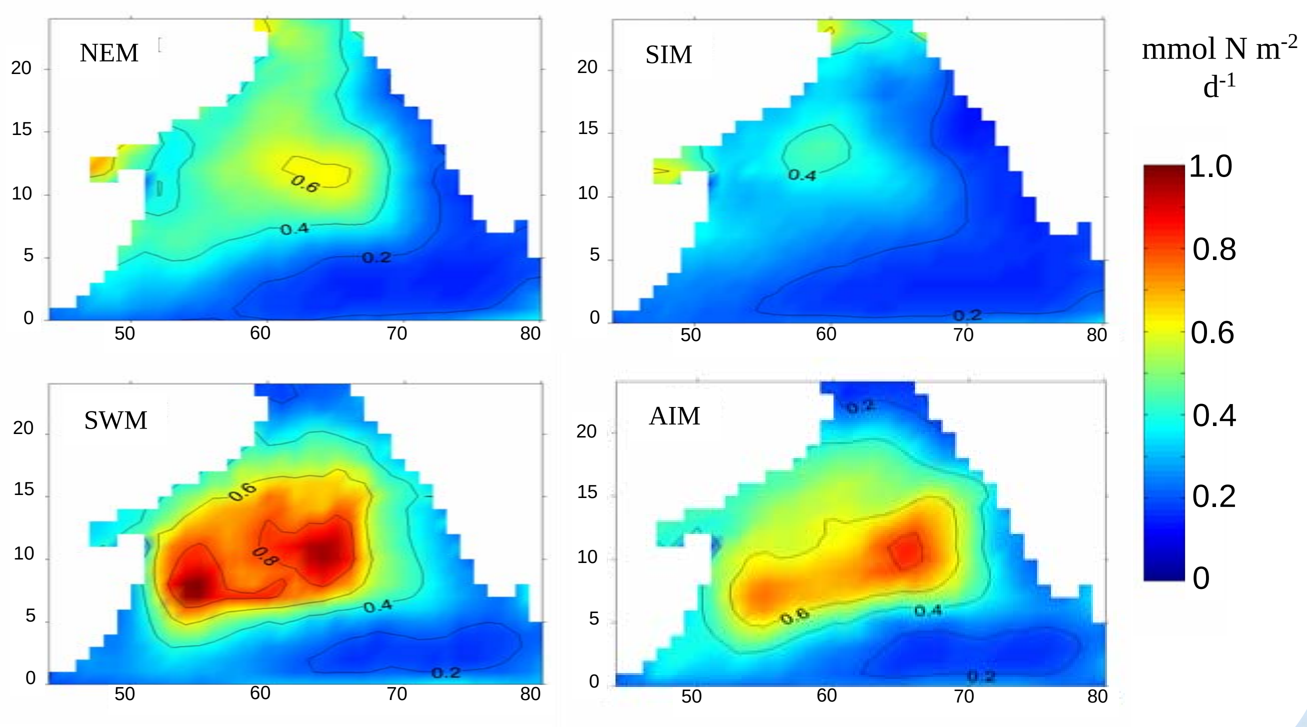
Denitrification, 137-650 m



Total = 26.2 Tg N yr^{-1}

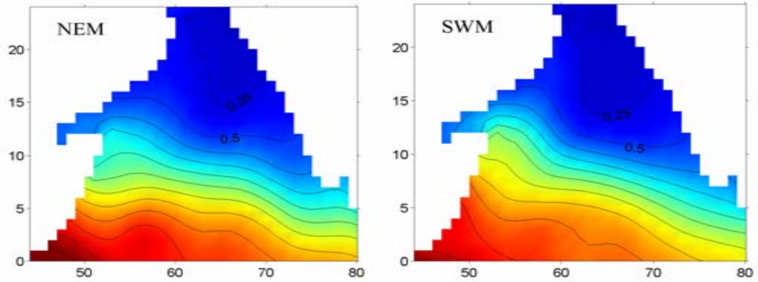
97% denitrification fuelled by detritus

Remineralisation, 137-650 m

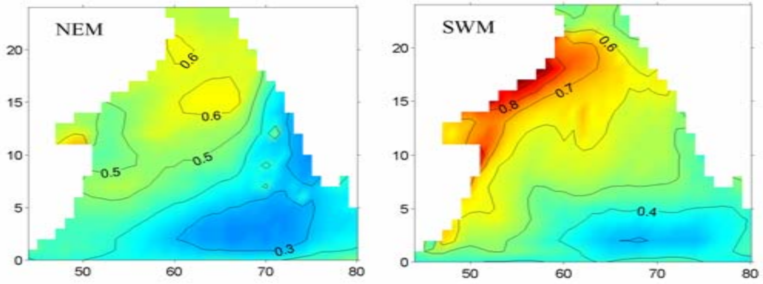


Comparison: NEM and SWM

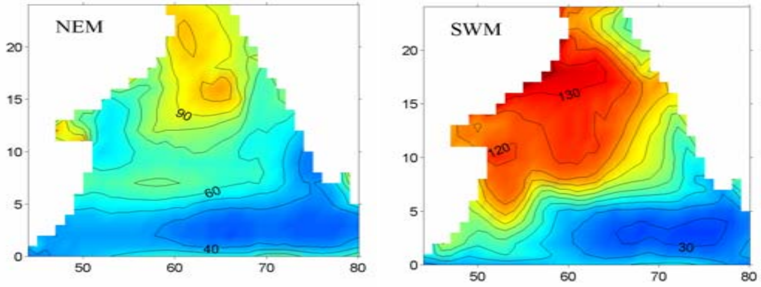
oxygen



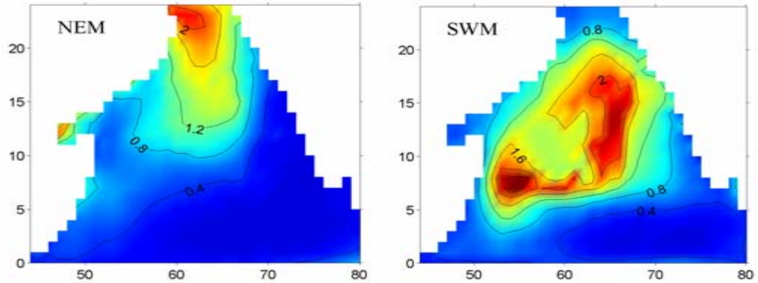
chlorophyll



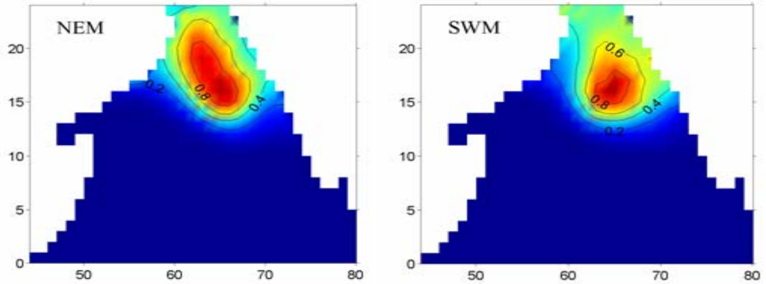
primary production



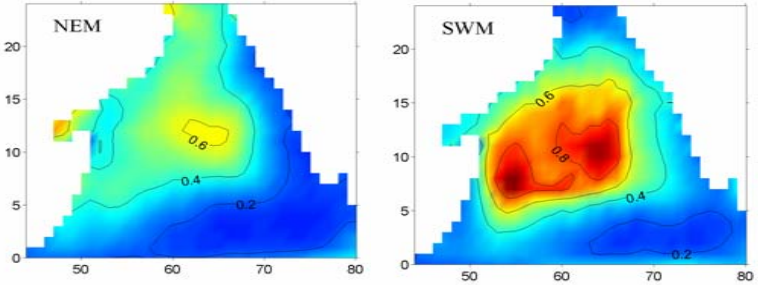
detritus flux



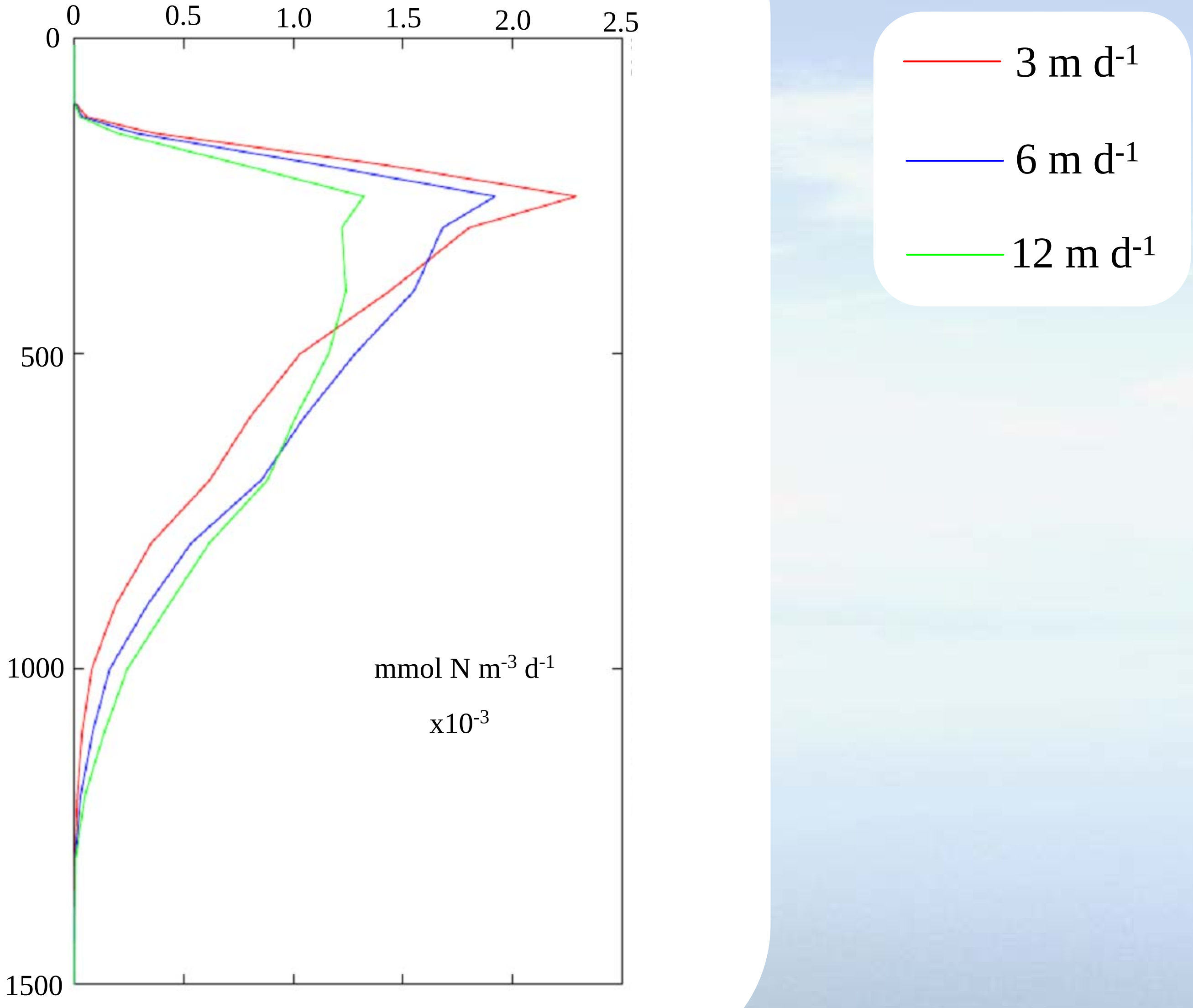
denitrification



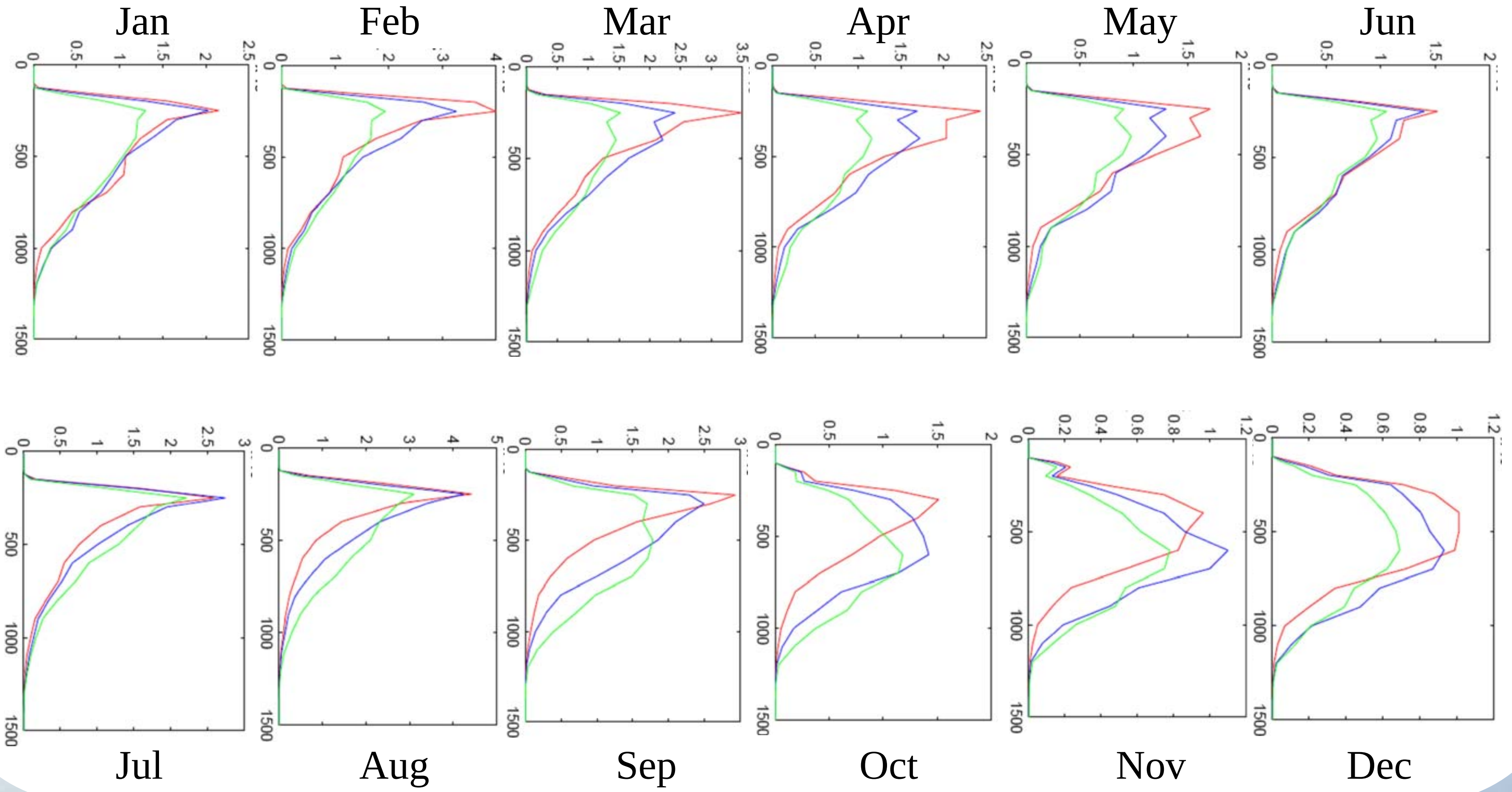
remineralisation



Mean annual denitrification

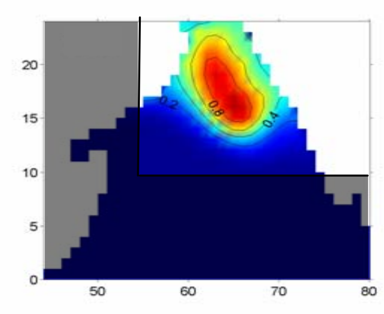


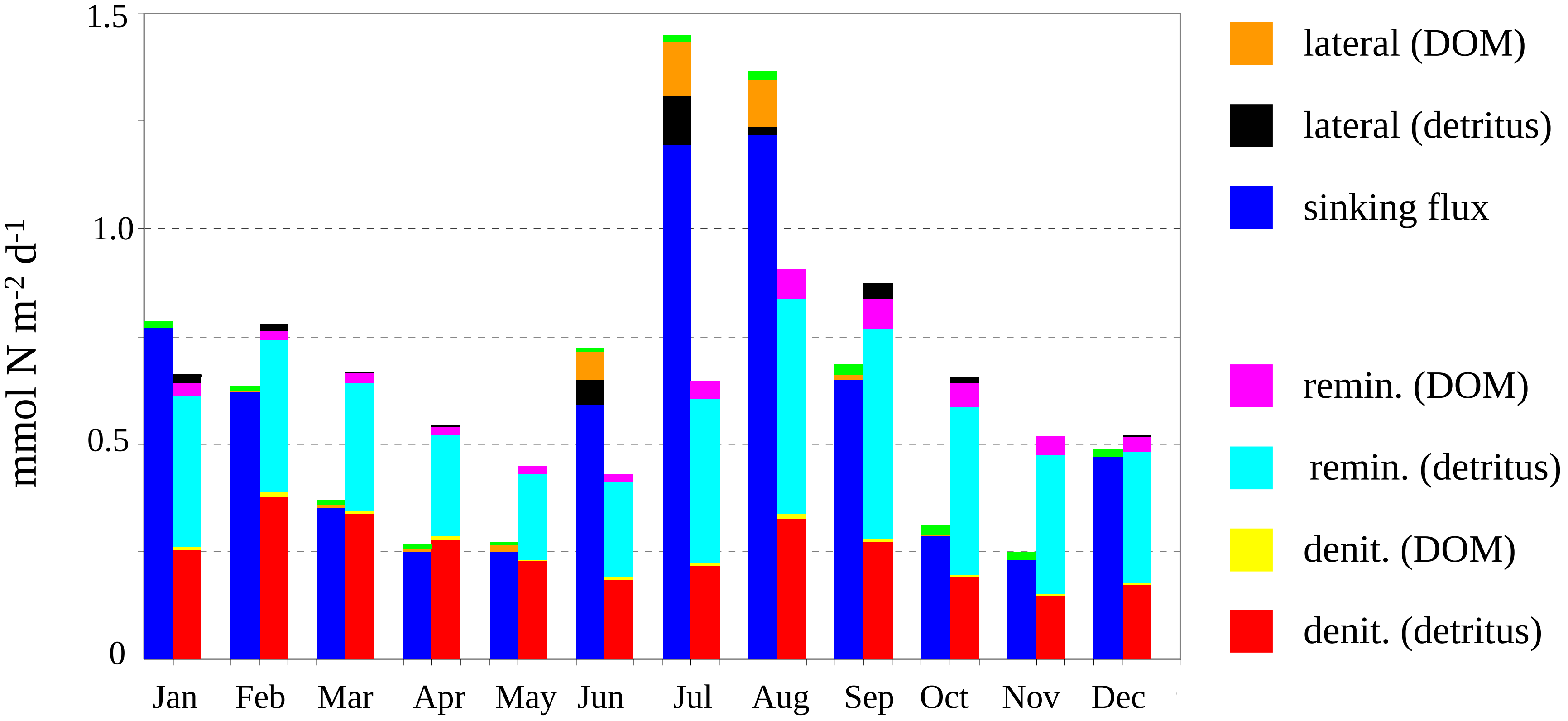
Monthly denitrification profiles



Sub-euphotic zone N budget (137 – 650 m)

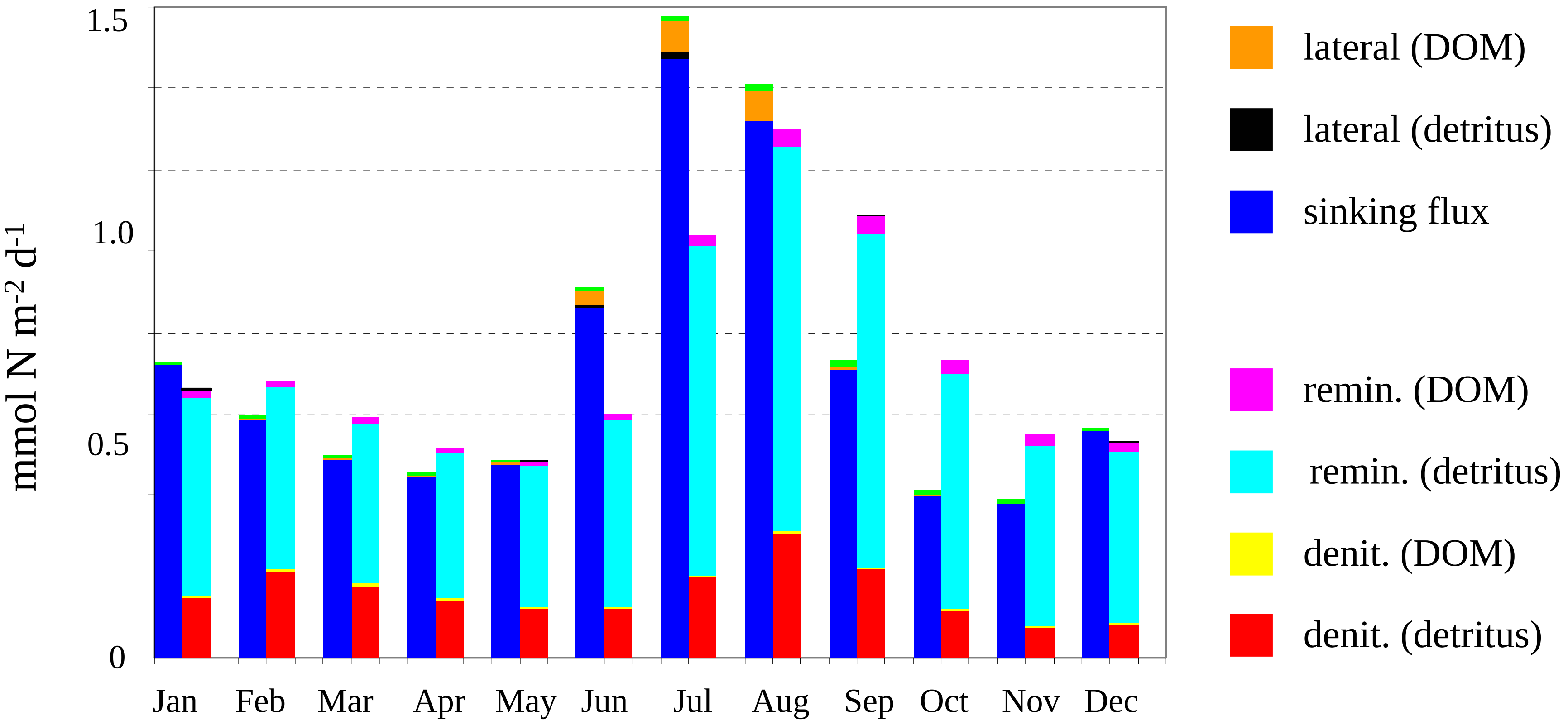
D sinking = 3 m d^{-1}





Sub-euphotic zone N budget (137 – 650 m)

D sinking = 12 m d^{-1} (total denit. = 25.7 Tg yr^{-1})



Is vertical input of detritus sufficient to meet bacterial carbon demand?

Ducklow et al. (1993, 2000):

Particle flux at 100 m varied between 8.3 and 25.6 mg C m^{-2} d^{-1} (mean 18.8 mg C m^{-2} d^{-1}) (data of Zietzshcel)

BP (100-1000 m): 28.5 mg C m^{-2} d^{-1}

If BGE = 0.5, then BCD is 57 mg C m^{-2} d^{-1}

If BGE = 0.15, then BCD is 190 mg C m^{-2} d^{-1}

But balance is achieved in the model with minimal lateral inputs of organic matter, so how can the C budget be explained?

Mean particle flux in model is (assuming C/N=8.4): 73.6 mg C m^{-2} d^{-1}

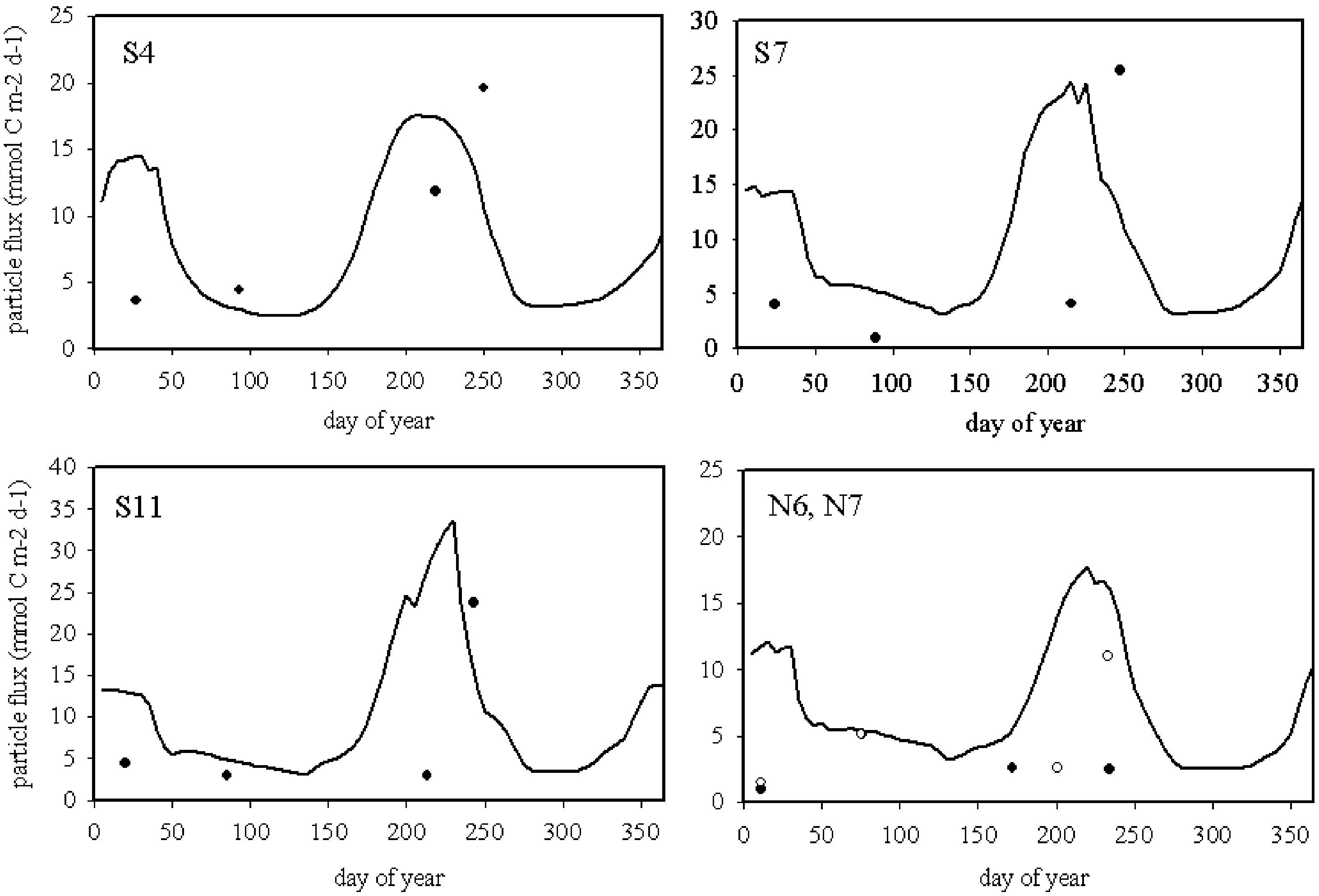
N consumed in remineralisation and denitrification is 0.629 mmol N m^{-2} d^{-1}

Multiplying by 8.4 gives 63.4 mg C m^{-2} d^{-1}

If BGE = 0.5 then BP (137-650 m) = 31.7 mg C m^{-2} d^{-1}

If BGE = 0.15 then BP (137-650 m) = 9.5 mg C m^{-2} d^{-1}

Particle flux



Conclusions

- Zones of denitrification and primary production are geographically separated (oxygen)
- Greatest denitrification occurs during NEM because of high primary production in northern Arabian Sea, where oxygen is low
- Detritus is the primary substrate contributing to both denitrification and remineralisation below the euphotic zone
- Lateral transport of organic matter is relatively unimportant in N budget below euphotic zone. But does shift primary production offshore in the euphotic zone
- Detritus sinking speed in model affects predicted timing of denitrification, but not annual total.
- Detritus flux and BP below euphotic zone are in balance in the model, but predicted detritus flux is greater than previous estimates.