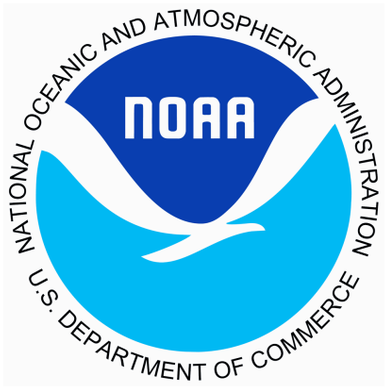
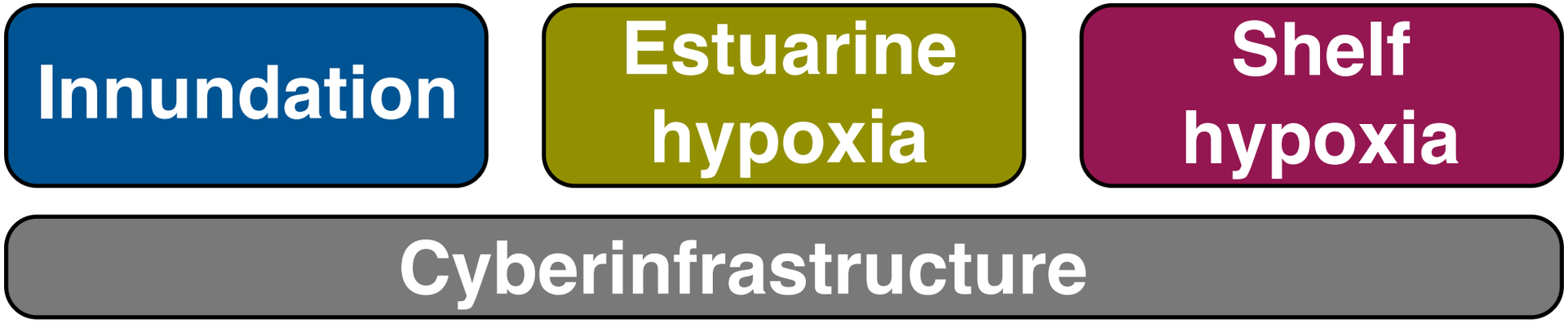
Sensitivity of hypoxia predictions to sediment oxygen consumption and model nesting

Results from the COMT Shelf Hypoxia Team

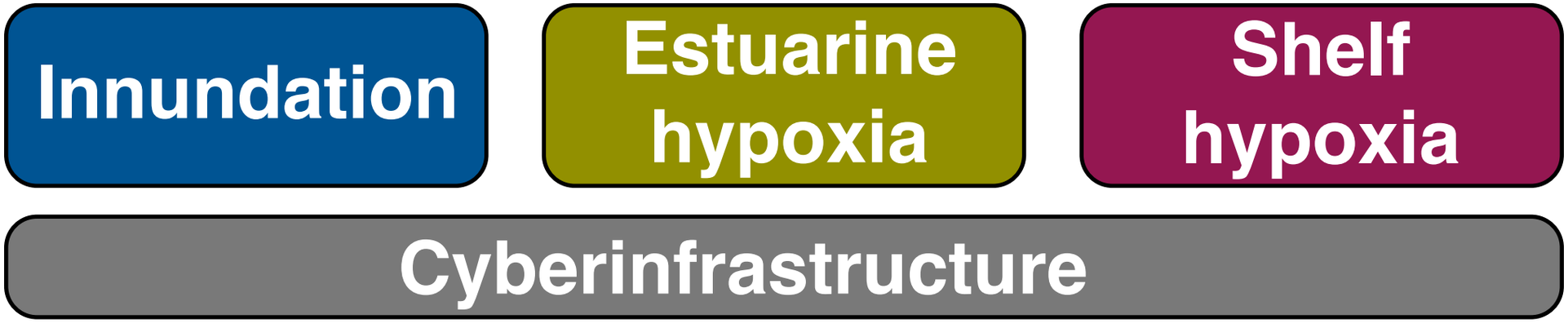


NOAA NGOMEX
and
U.S. IOOS COMT

Coastal & Ocean Modeling Testbed



Coastal & Ocean Modeling Testbed



Shelf Hypoxia (SH) Team: collaborators from TAMU, NRL, FSU, NOAA CSDL, UDel, Dalhousie, NGI

Objectives included:

- investigate sensitivity of hypoxia predictions to nesting configurations
- transition ROMS Hypoxia module to FVCOM at NOAA CSDL

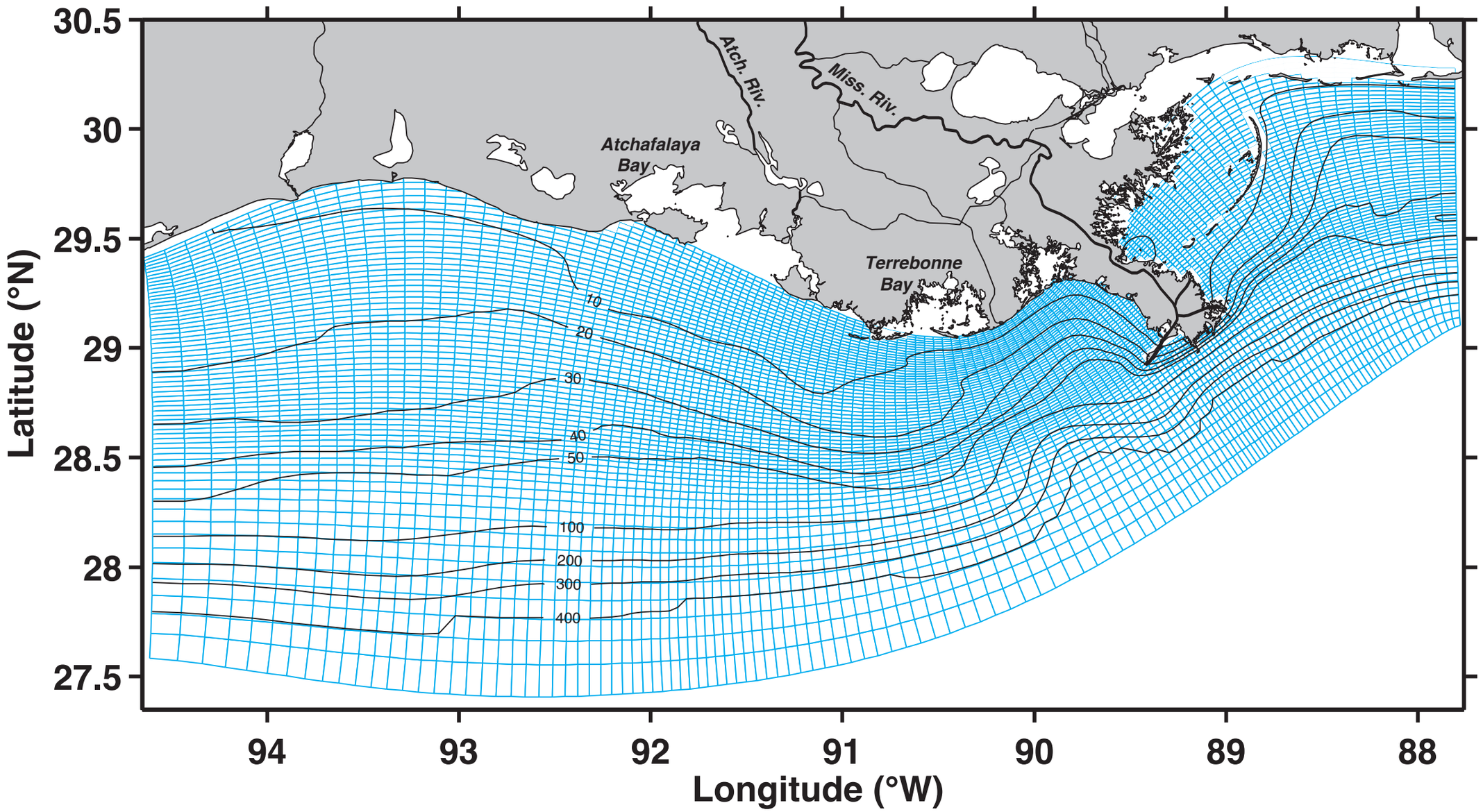
JGR Special Issue (5 papers): Marta-Almeida et al. (2013), Fennel et al. (2013), Mattern et al. (2013), Harding et al. (in review), Lehrter et al. (in review)

Related management questions

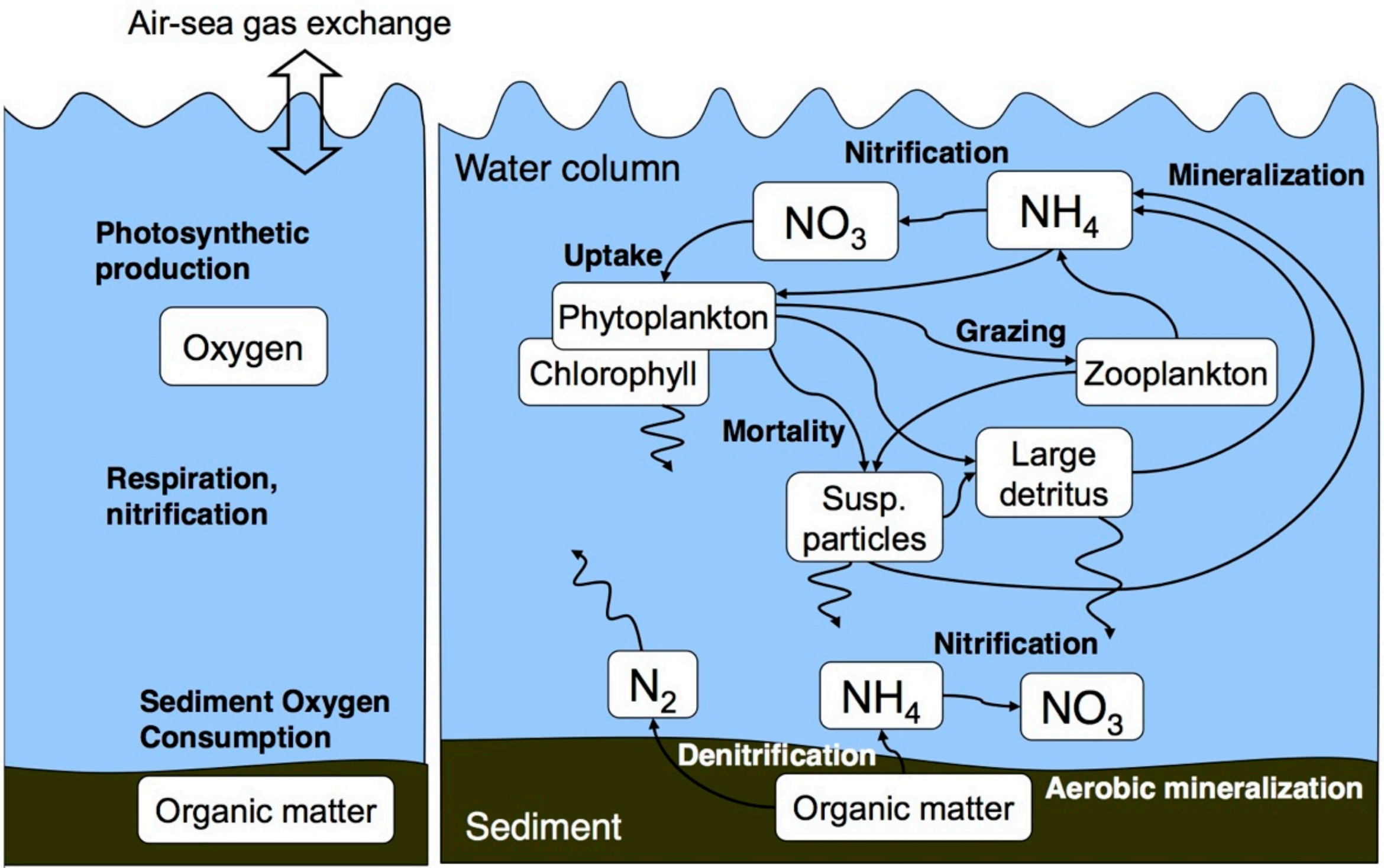
1. Relationship between nutrients and hypoxia
2. Influence of freshwater & stratification
3. Nutrient reductions required
4. Error and timing
5. Interim nutrient reductions
6. Influences of circulation and weather
7. Effect of river diversions etc.
8. Long-term climate change effects
9. *Impacts on living resources*

Related management questions

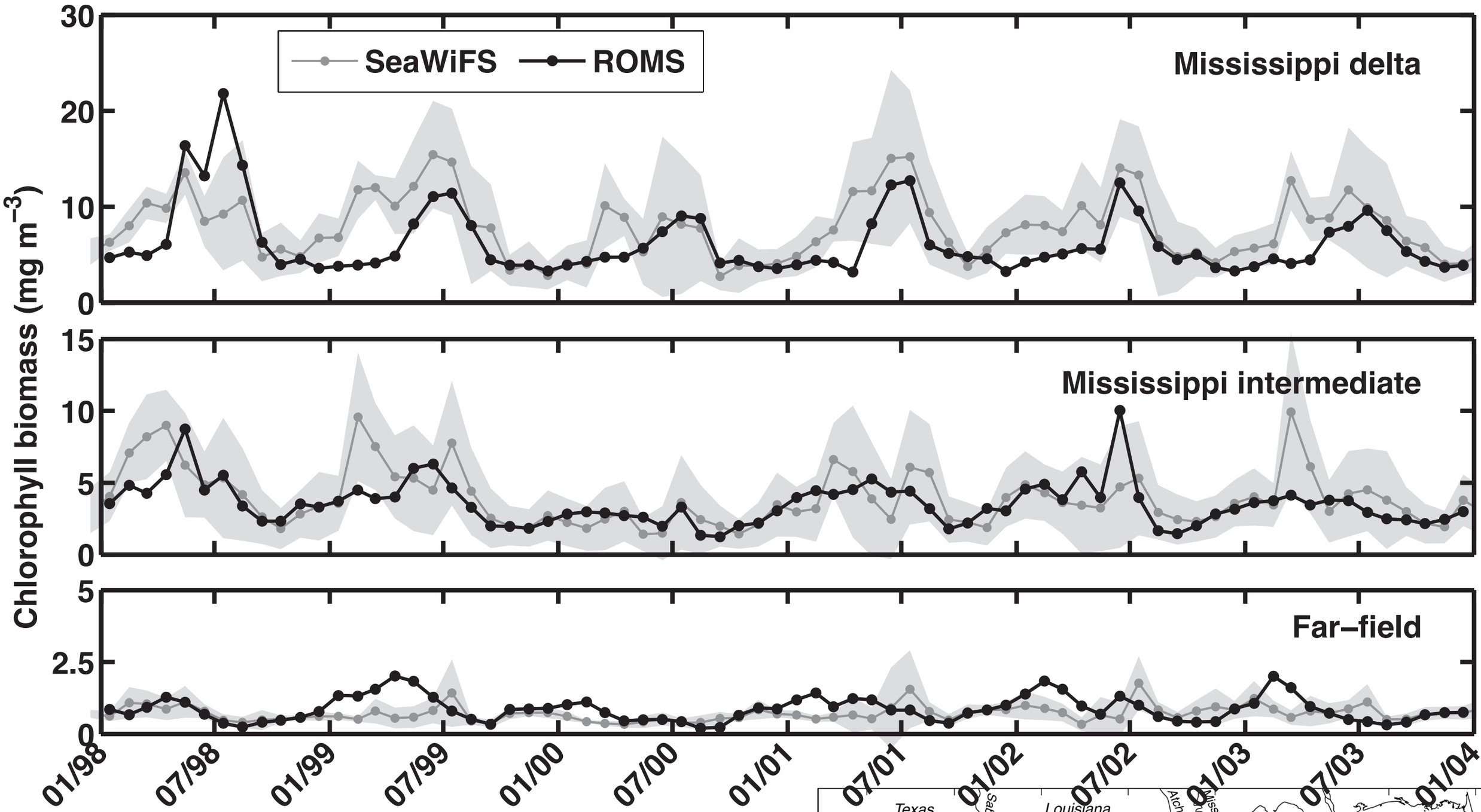
1. Relationship between nutrients and hypoxia
2. **Influence of freshwater & stratification**
3. Nutrient reductions required
4. Error and timing
5. Interim nutrient reductions
6. **Influences of circulation and weather**
7. Effect of river diversions etc.
8. Long-term climate change effects
9. *Impacts on living resources*

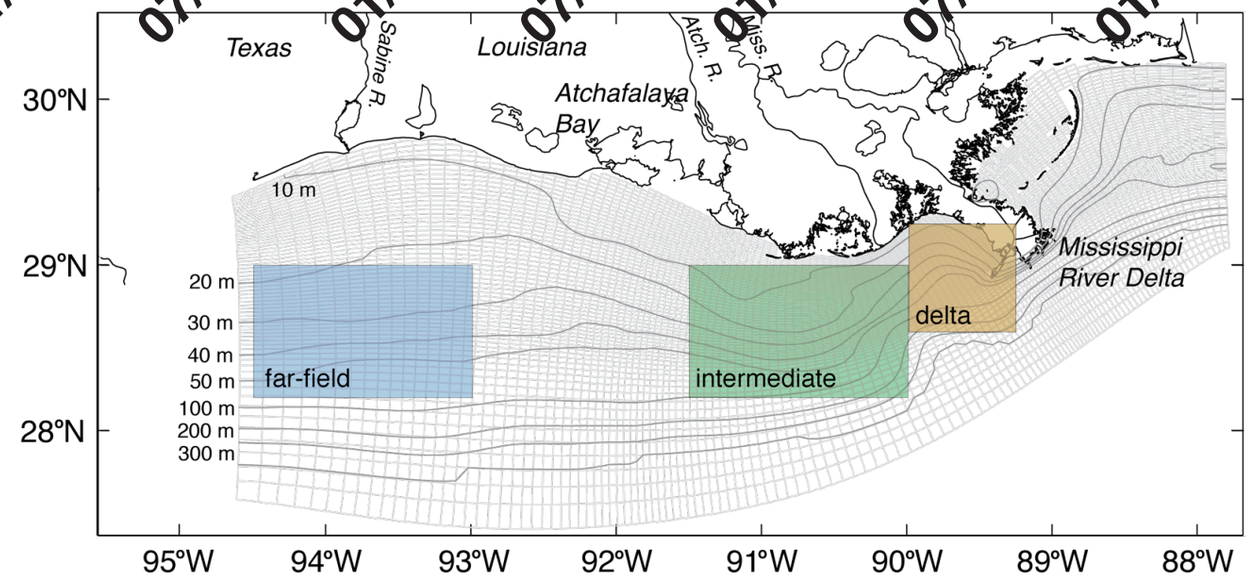


Physical model: ROMS v3.0
Biological model: BIO_FENNEL with OXYGEN
Resolution: 1-20 km in horizontal, 20 or 30 vertical layers
Forcing: 3-hourly NCEP NARR winds; climatological surface heat and freshwater fluxes
River inputs: daily measurements of FW input by U.S. Army Corps of Engineers; monthly estimates of nutrient and particulate matter loads from USGS
Horizontal b.c.s: climatology, operational HYCOM or IASNFS for physics; climatology for biology

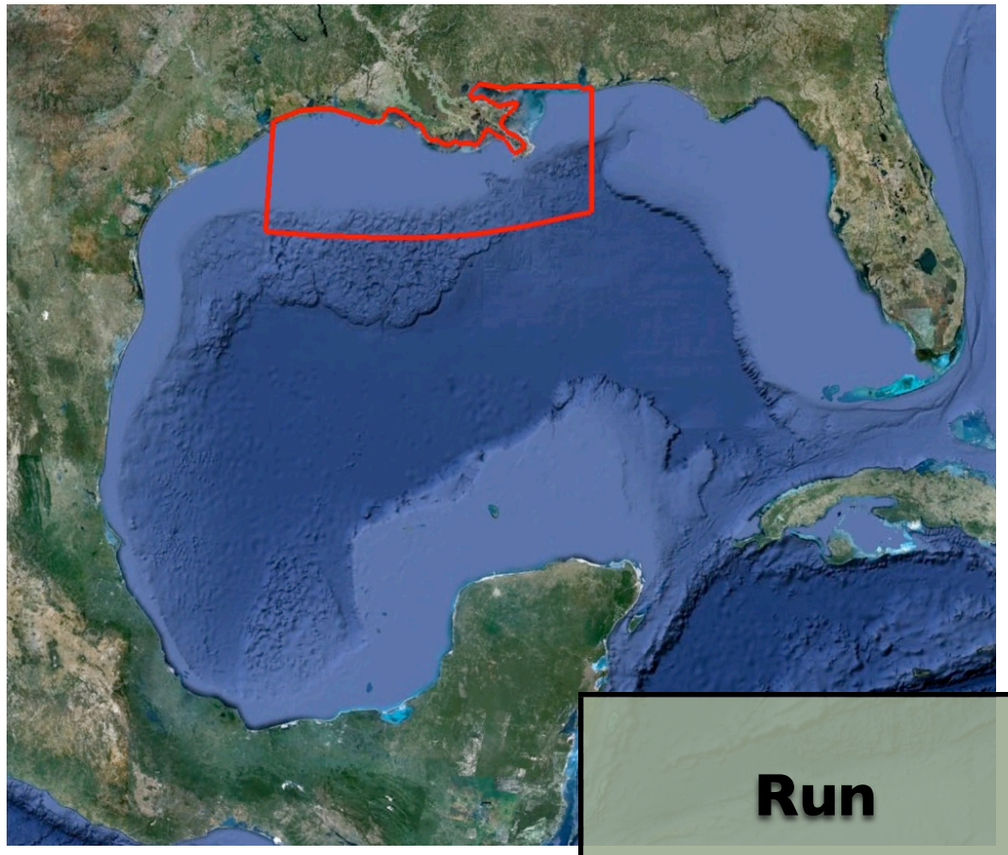


Fennel et al. *Biogeosciences* (2011)
Laurent et al. *Biogeosciences* (2012)





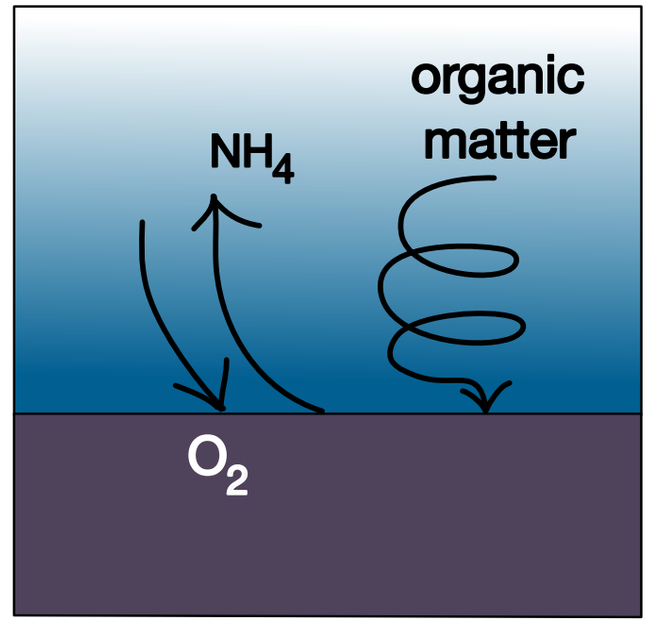
Fennel et al. *Biogeosciences* (2011)
Laurent et al. *Biogeosciences* (2012)



Run	SOC treatment	# vertical layers	horizontal boundaries
A20clim	IR	20	climatological
B20clim	H&D	20	climatological
C20clim	M&L	20	climatological
A30clim	IR	30	climatological
B30clim	H&D	30	climatological
A30HYC	IR	30	HYCOM
B30HYC	H&D	30	HYCOM
A30IAS	IR	30	IASNFS
B30IAS	H&D	30	IASNFS

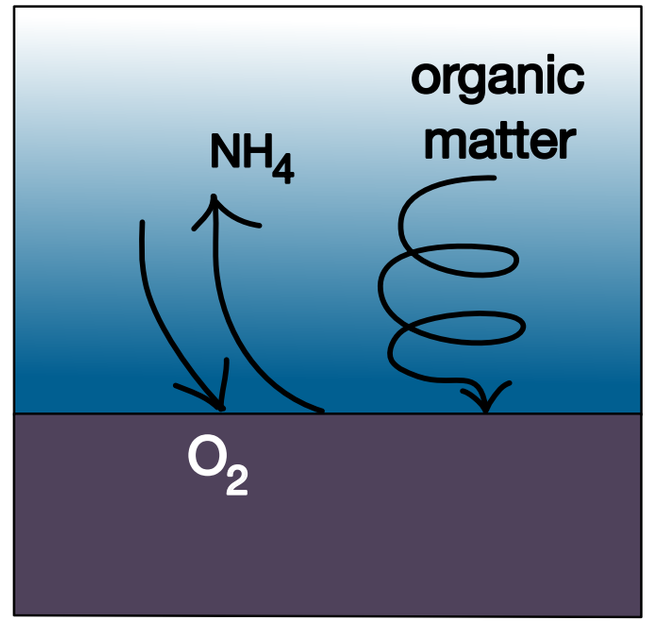
Three treatments of Sediment Oxygen Consumption (SOC):

(A) Instantaneous Remineralization or IR
(depends only on organic matter flux)

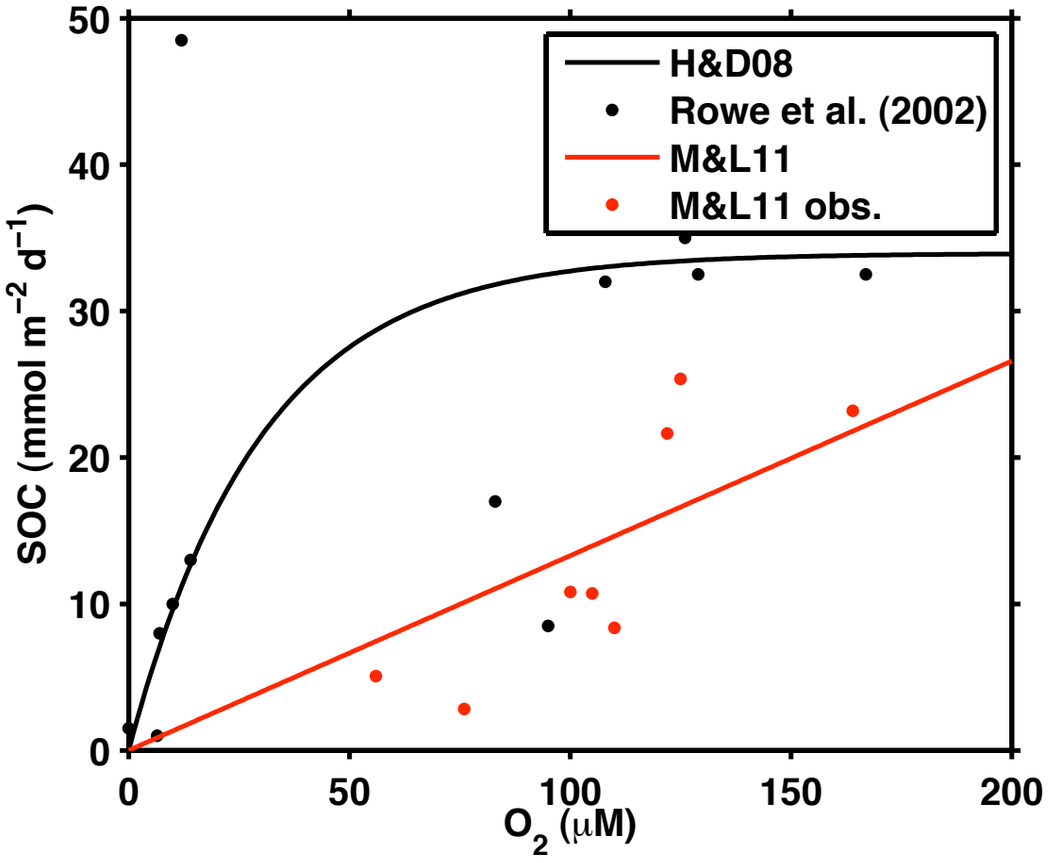


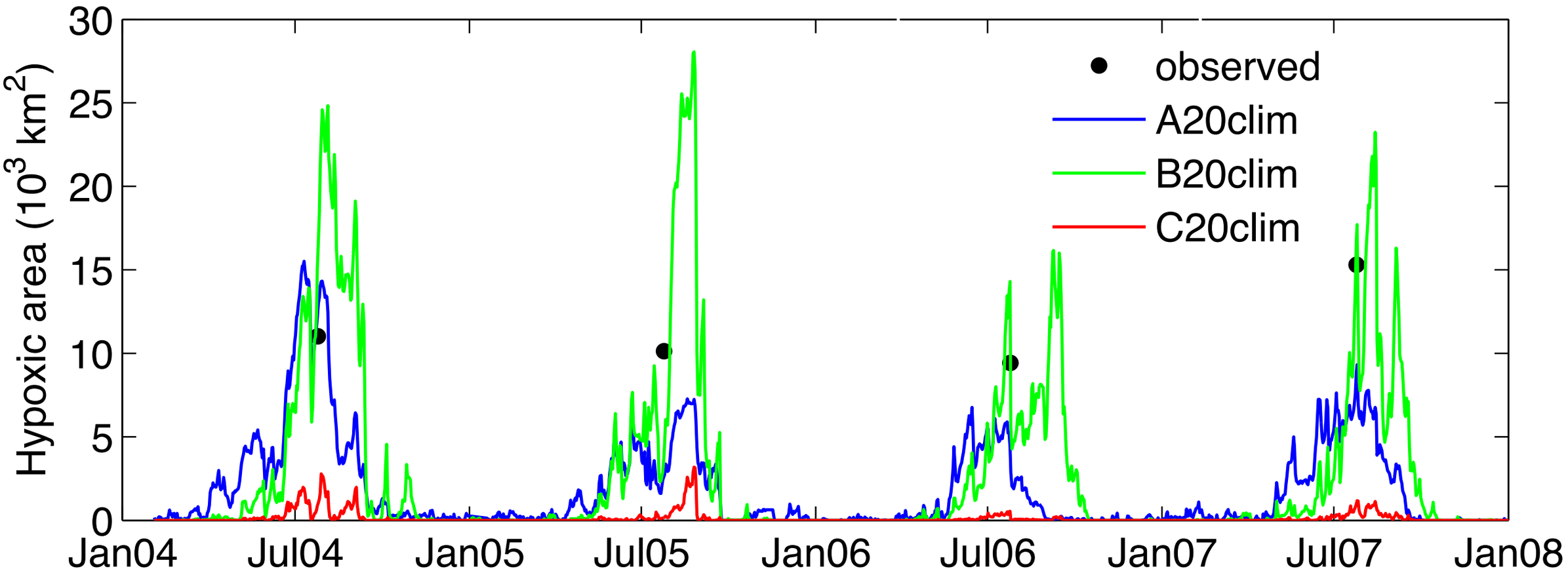
Three treatments of Sediment Oxygen Consumption (SOC):

(A) Instantaneous Remineralization or IR
(depends only on organic matter flux)



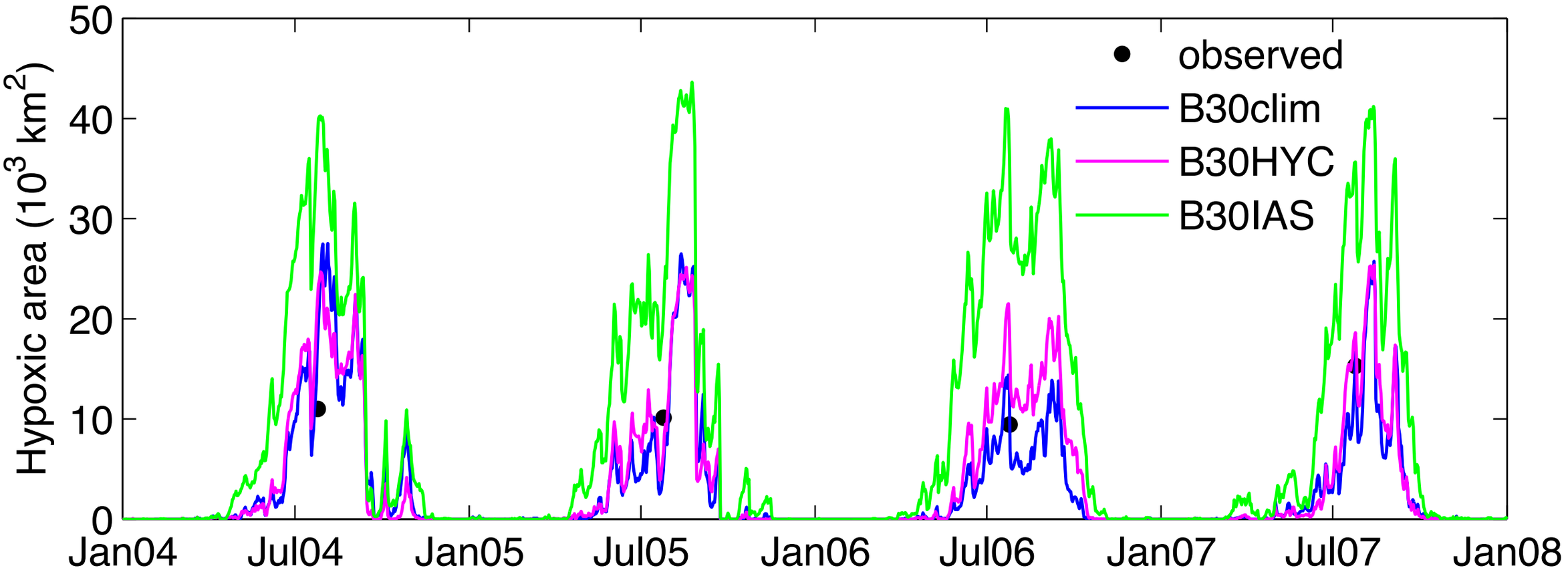
SOC parameterizations (depend on bottom water T and DO, but not organic matter flux)
(B) Hetland and DiMarco (2008) or H&D
(C) Murrell and Lehrter (2011) or L&M



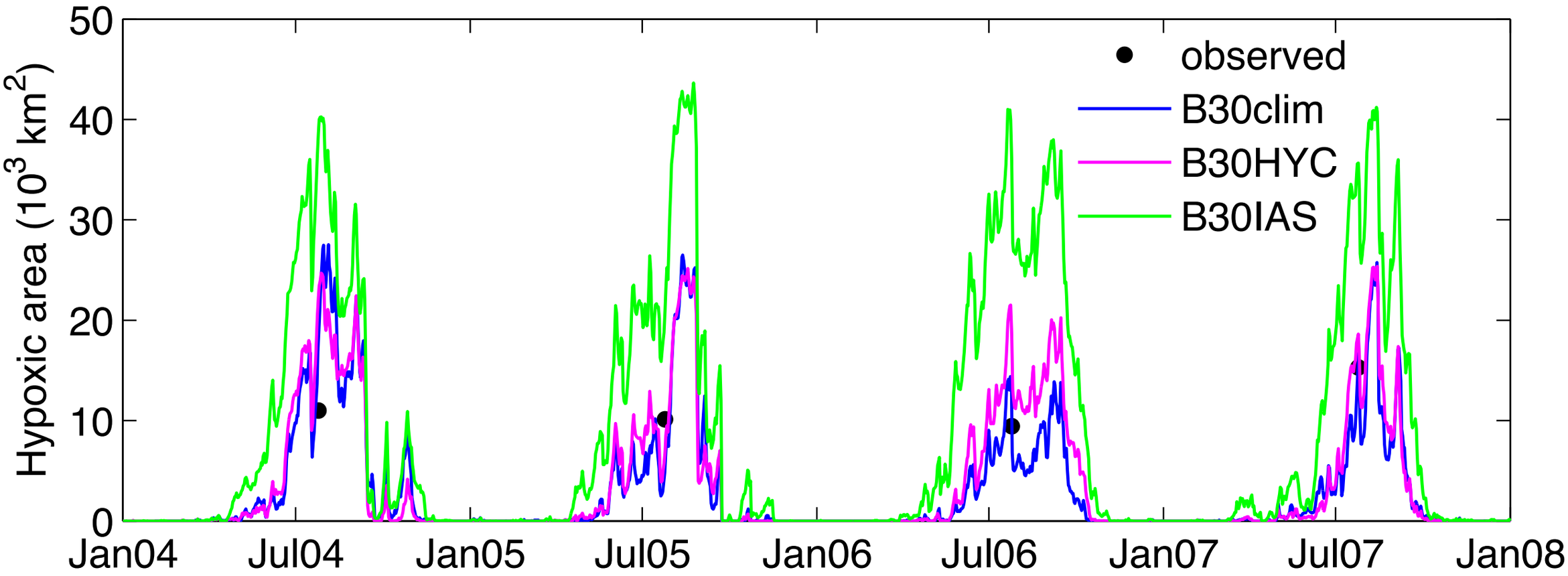


A: Instantaneous Remineralization
B: Hetland & DiMarco (2008)
C: Murrell & Lehrter (2011)

Fennel et al. *JGR-Oceans* (2013)



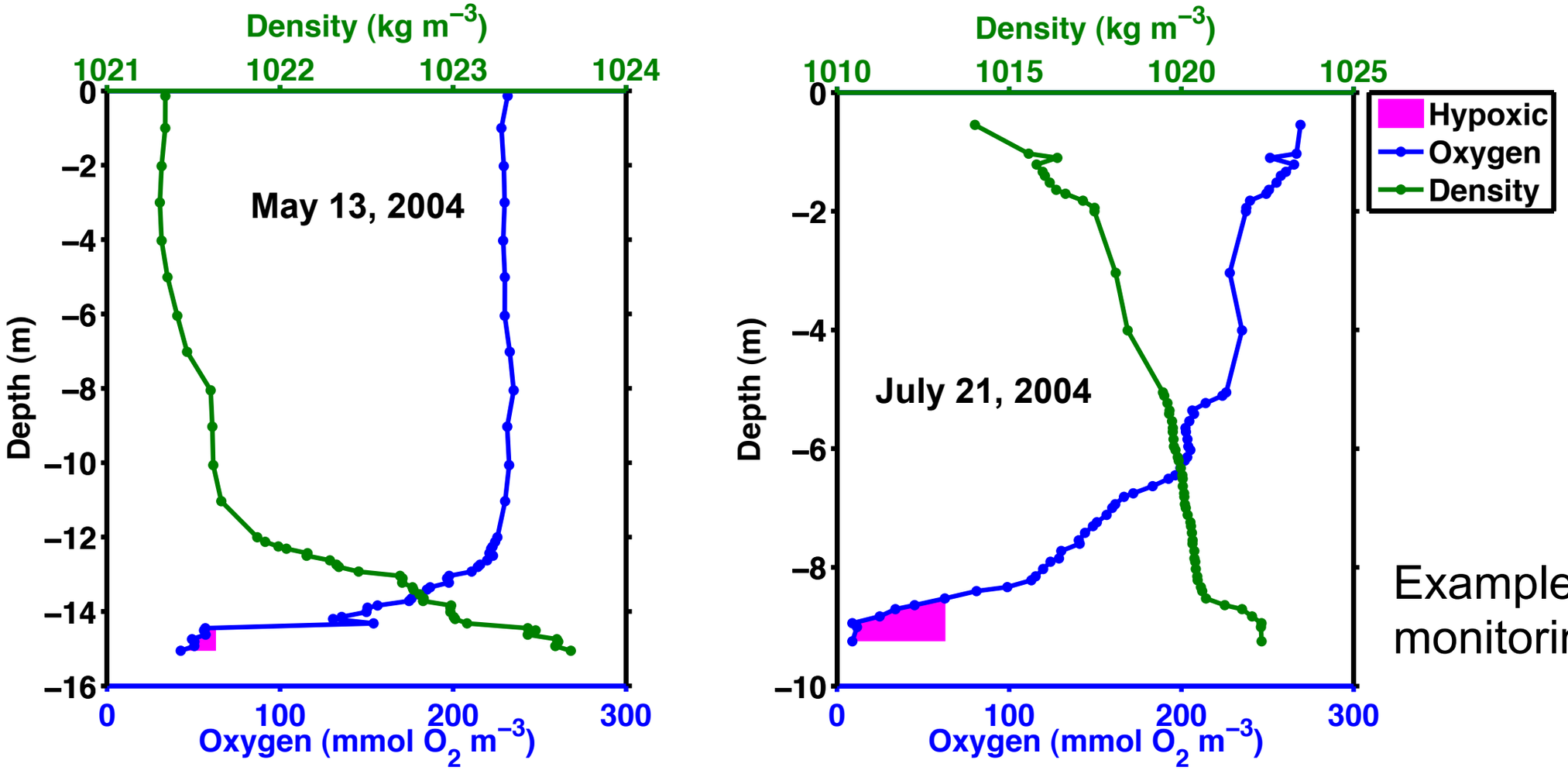
Fennel et al. *JGR-Oceans* (2013)



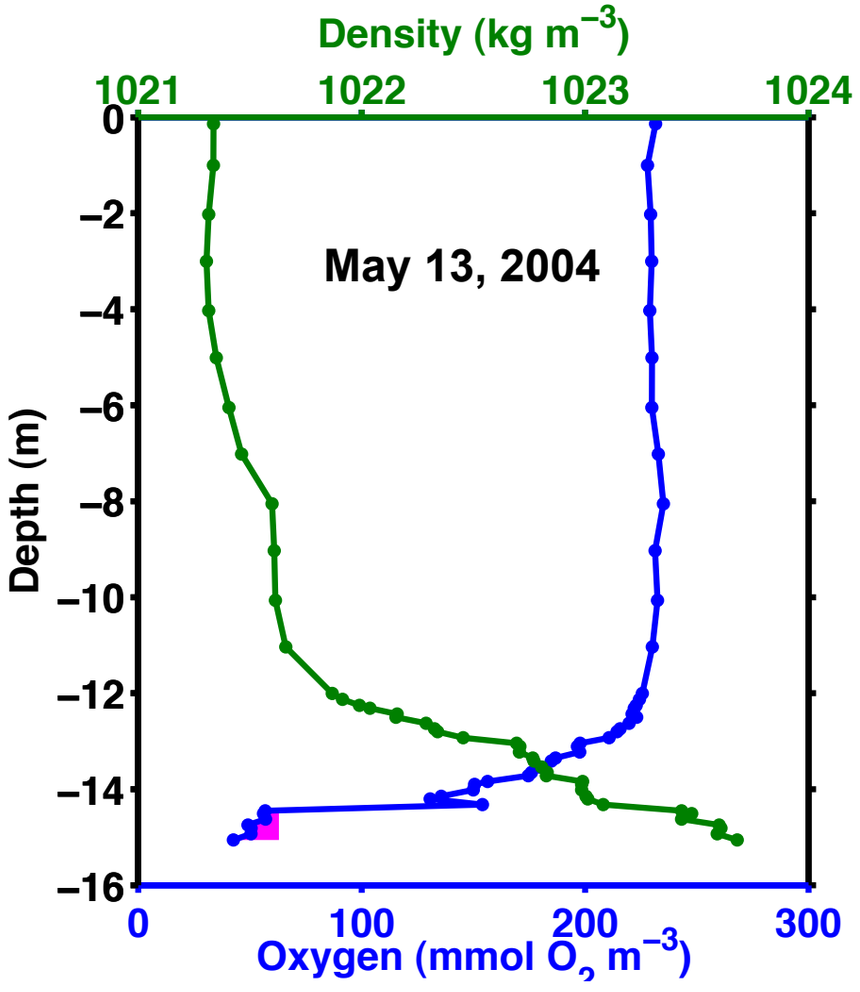
Why are hypoxia predictions so sensitive to SOC treatment?

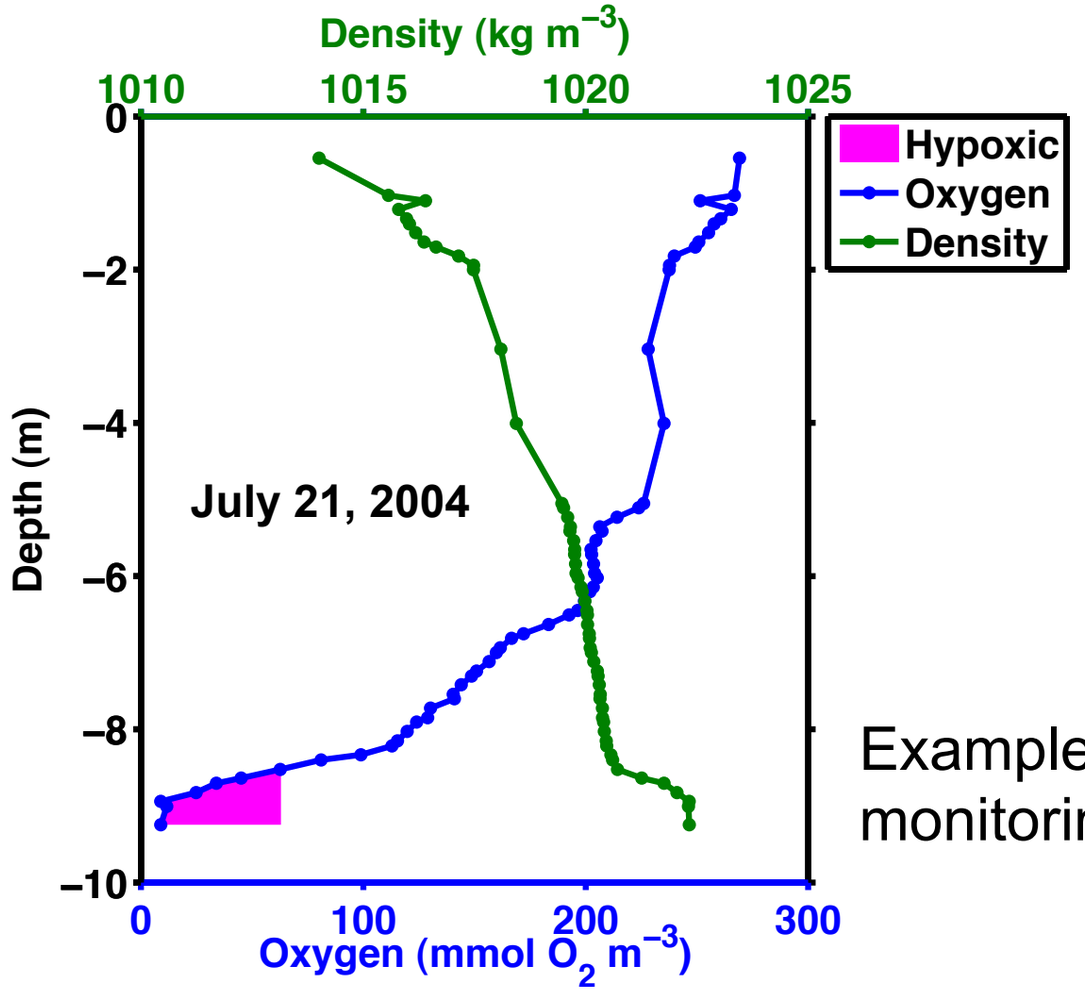
Why systematically higher for IASNFS boundaries?

Fennel et al. *JGR-Oceans* (2013)

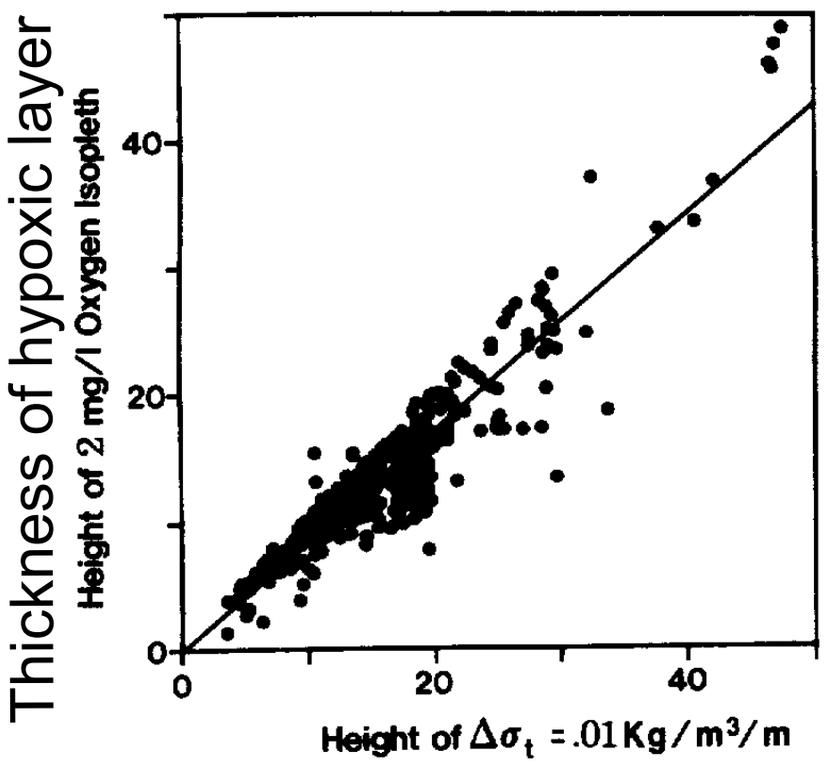


Examples of LUMCON monitoring observations





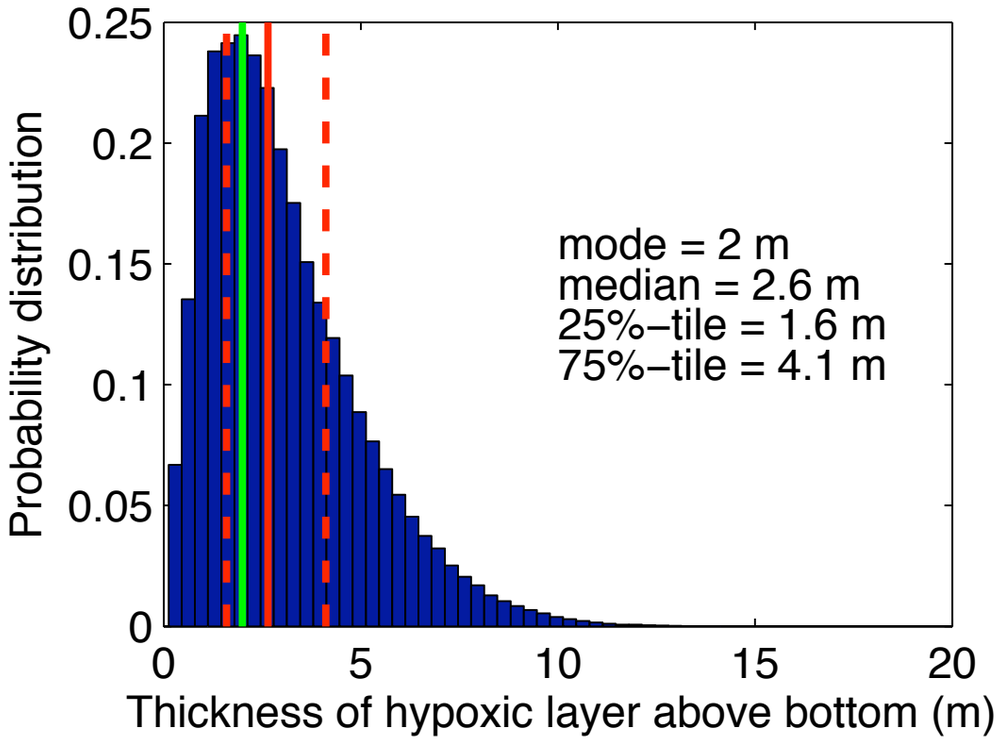
Examples of LUMCON monitoring observations

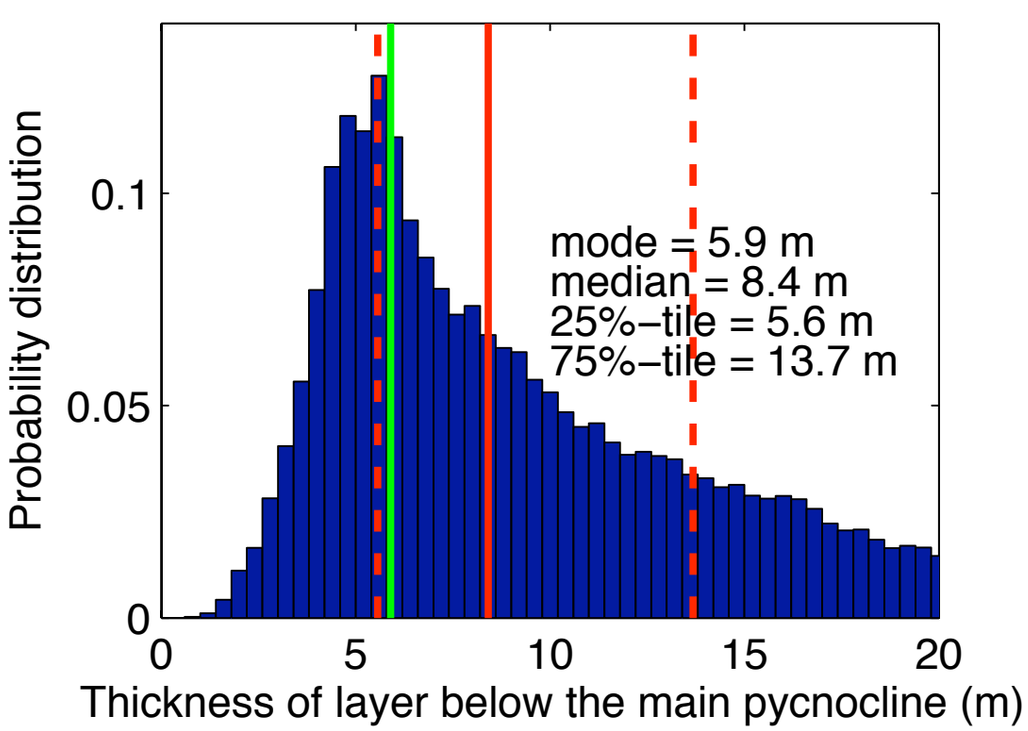


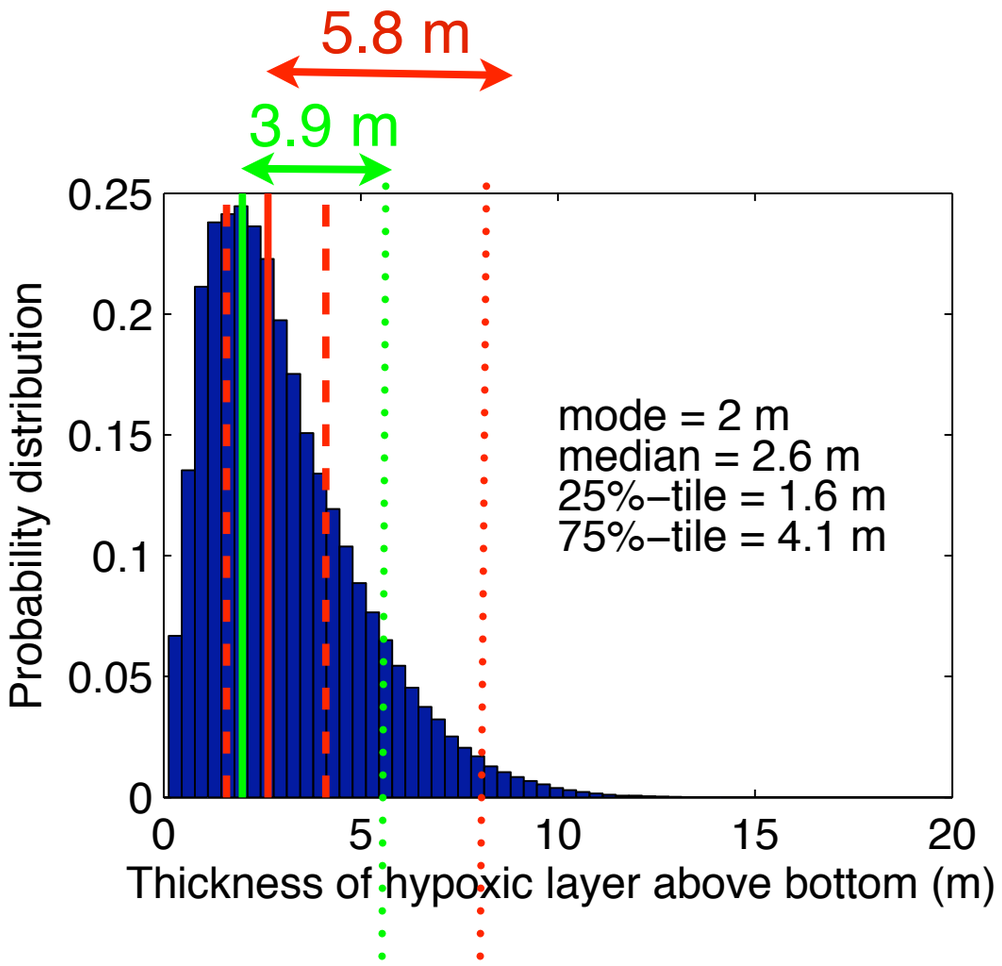
Wiseman et al., JMS (1997)

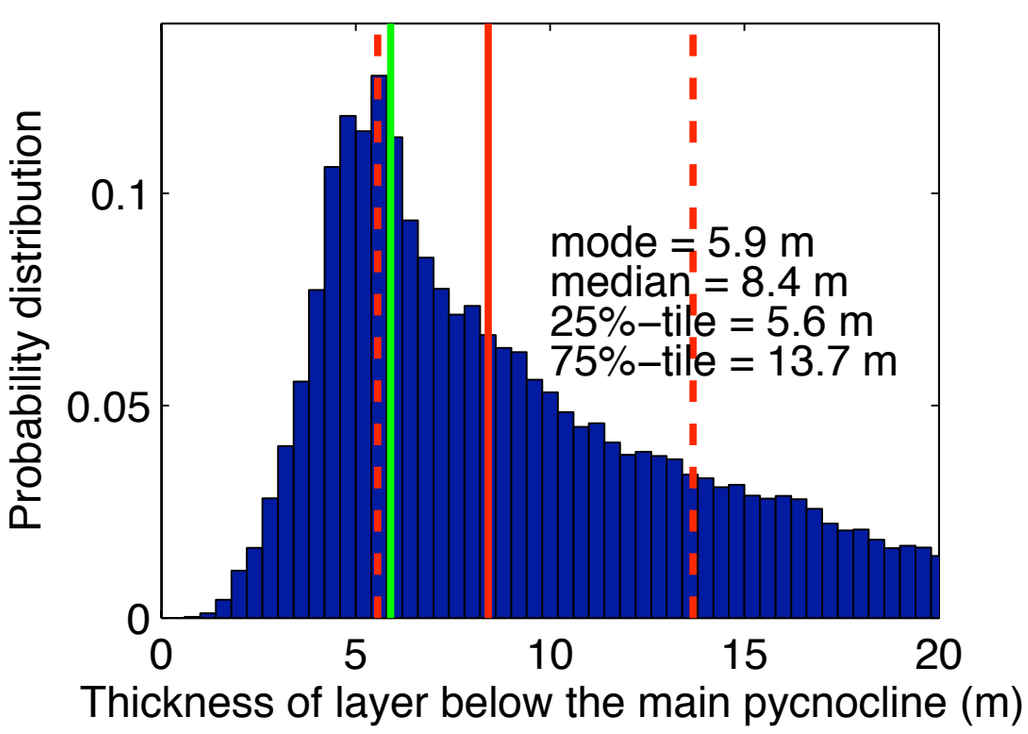
Thickness of the bottom boundary layer

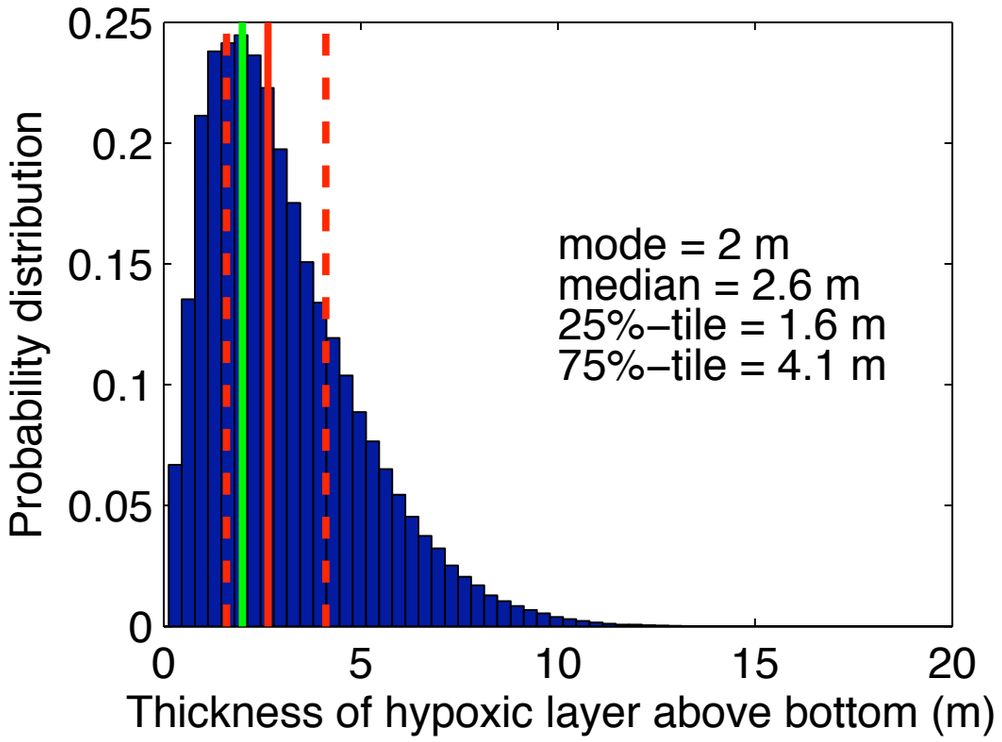
Hypoxia is essentially constrained to bottom boundary layer (BBL).

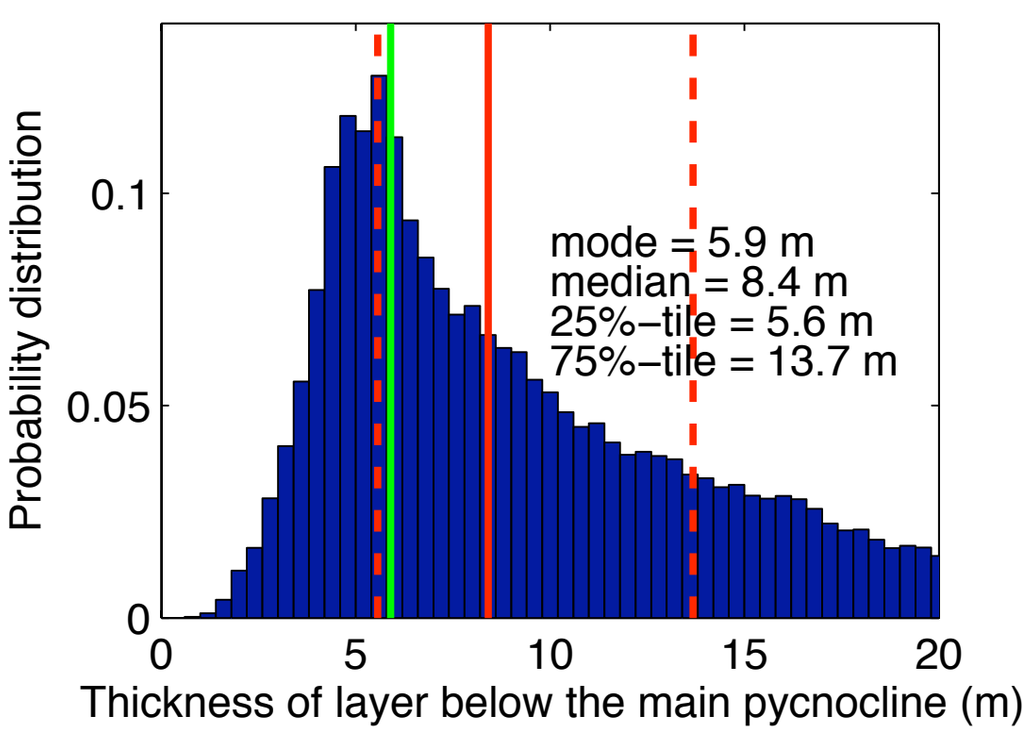

0.25
0.2
0.15
0.1
0.05
0
Probability distribution
mode = 2 m
median = 2.6 m
25%–tile = 1.6 m
75%–tile = 4.1 m
0
5
10
15
20
Thickness of hypoxic layer above bottom (m)

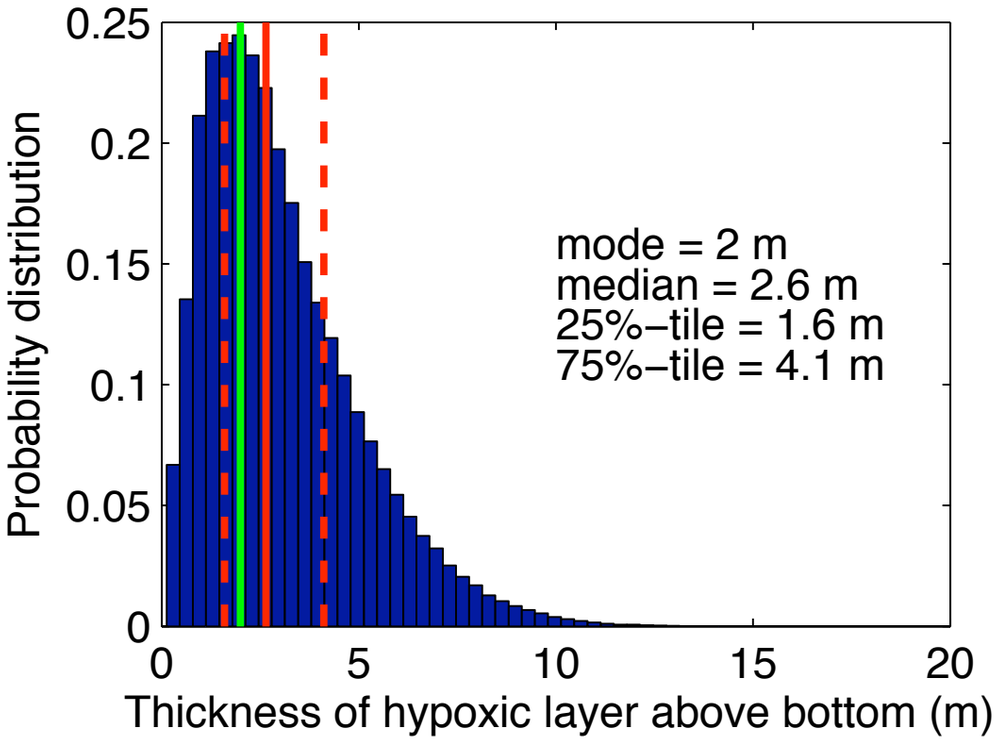

0.1
0.05
0
Probability distribution
mode = 5.9 m
median = 8.4 m
25%–tile = 5.6 m
75%–tile = 13.7 m
0
5
10
15
20
Thickness of layer below the main pycnocline (m)

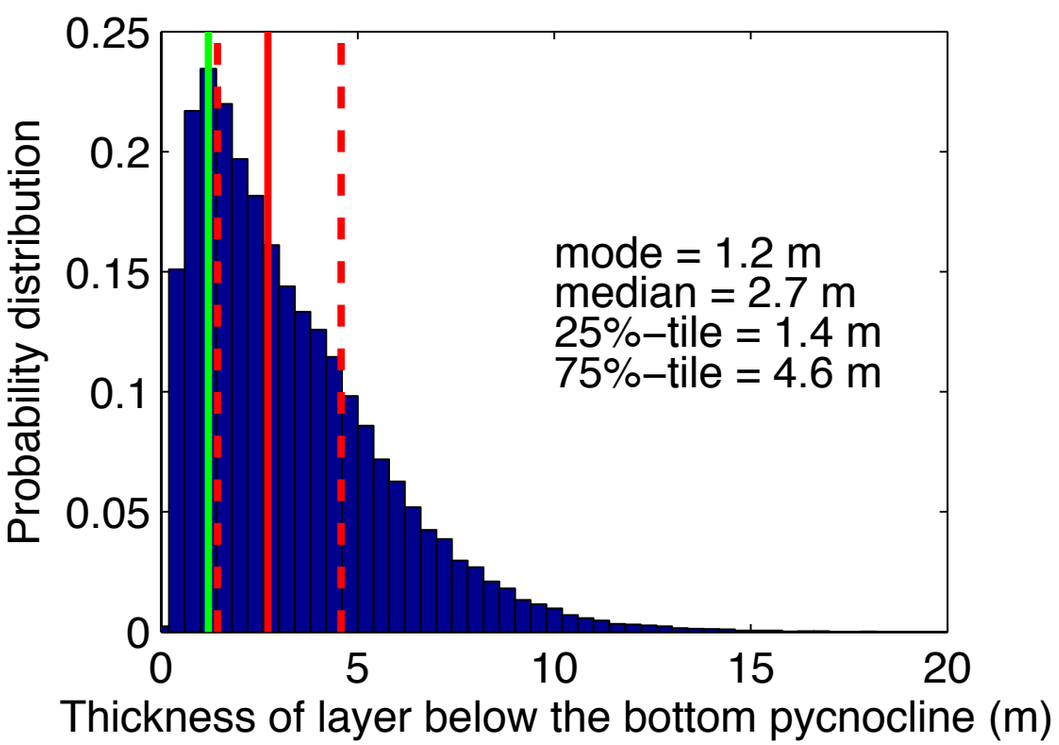

5.8 m
3.9 m
0.25
0.2
0.15
0.1
0.05
0
Probability distribution
mode = 2 m
median = 2.6 m
25%–tile = 1.6 m
75%–tile = 4.1 m
0
5
10
15
20
Thickness of hypoxic layer above bottom (m)

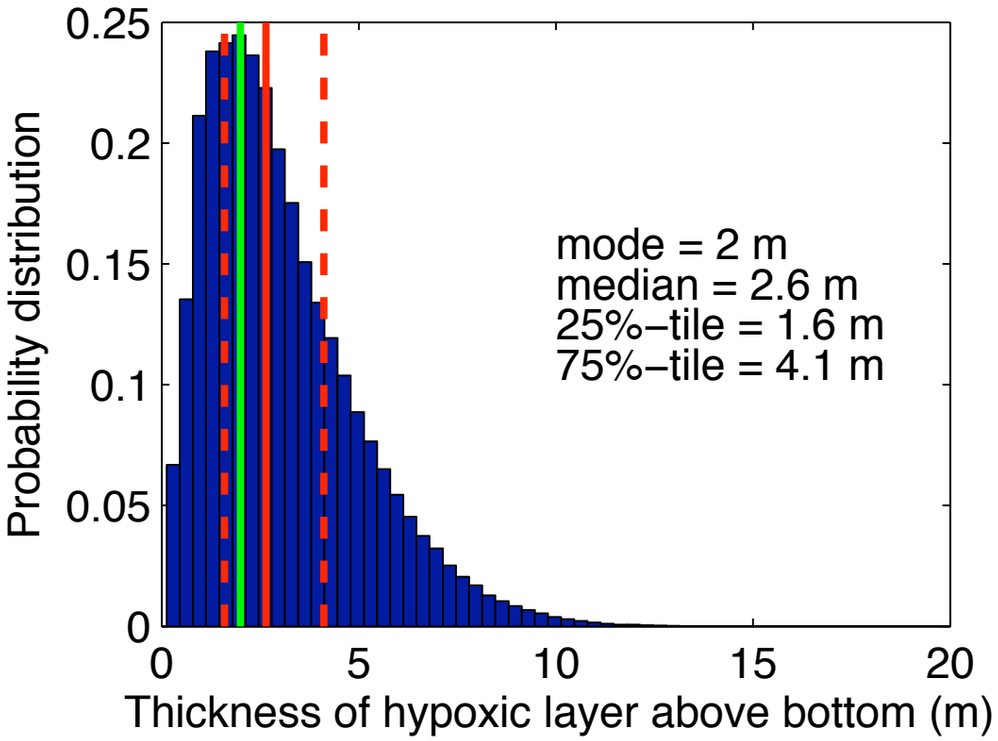

0.1
0.05
0
Probability distribution
mode = 5.9 m
median = 8.4 m
25%–tile = 5.6 m
75%–tile = 13.7 m
0
5
10
15
20
Thickness of layer below the main pycnocline (m)

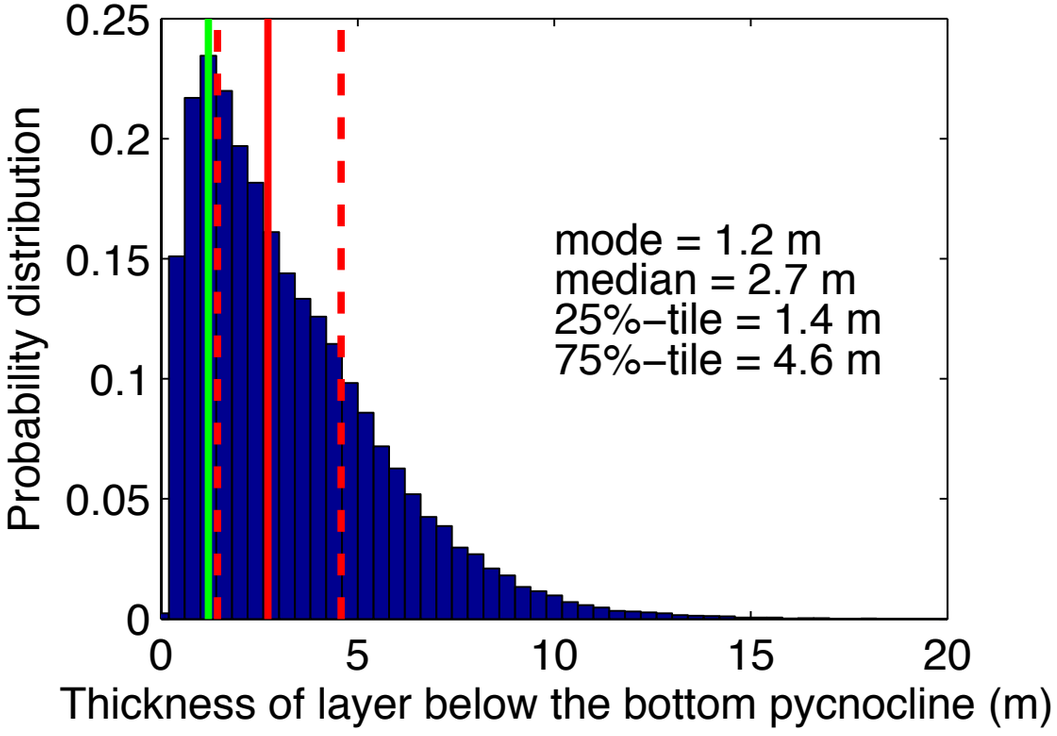

0.25
0.2
0.15
0.1
0.05
0
Probability distribution
mode = 2 m
median = 2.6 m
25%–tile = 1.6 m
75%–tile = 4.1 m
0
5
10
15
20
Thickness of hypoxic layer above bottom (m)

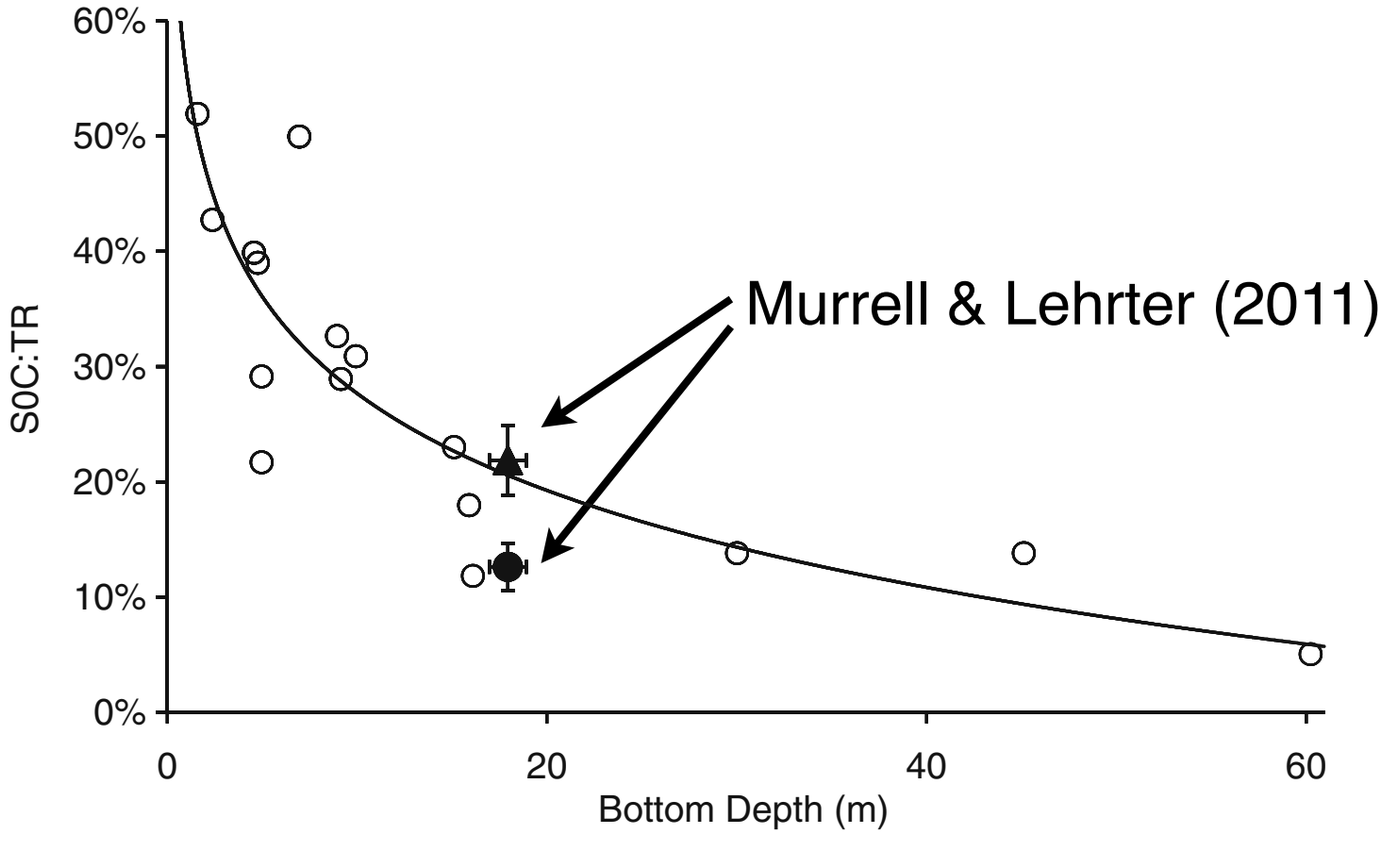

0.1
0.05
0
Probability distribution
mode = 5.9 m
median = 8.4 m
25%–tile = 5.6 m
75%–tile = 13.7 m
0
5
10
15
20
Thickness of layer below the main pycnocline (m)

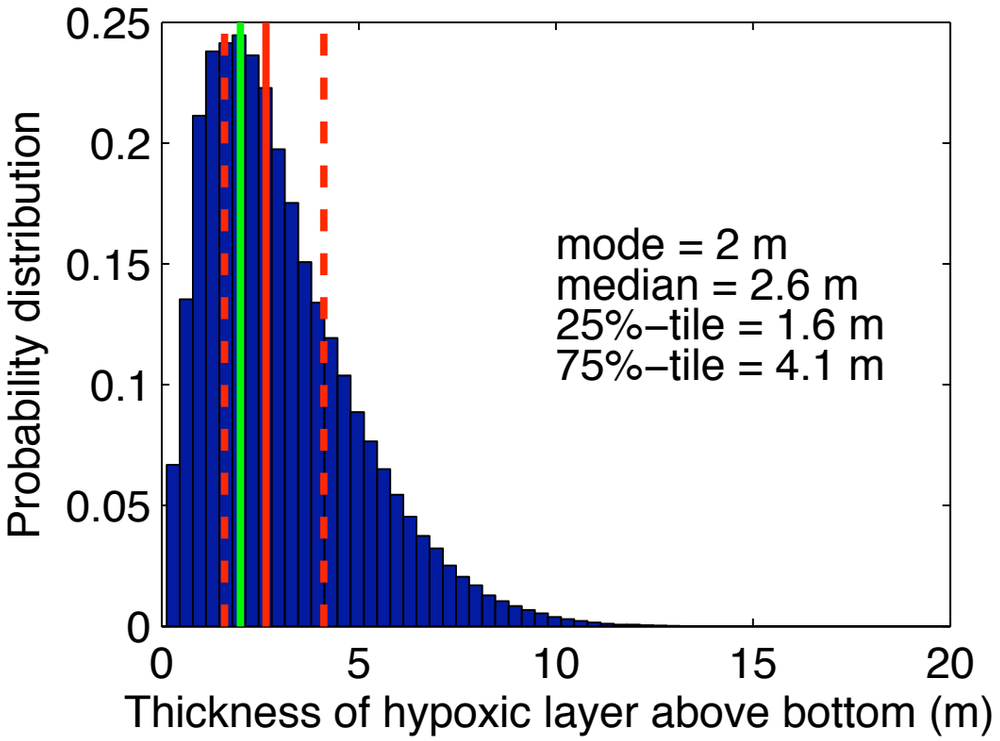

0.25
0.2
0.15
0.1
0.05
0
Probability distribution
0
5
10
15
20
Thickness of hypoxic layer above bottom (m)
mode = 2 m
median = 2.6 m
25%–tile = 1.6 m
75%–tile = 4.1 m

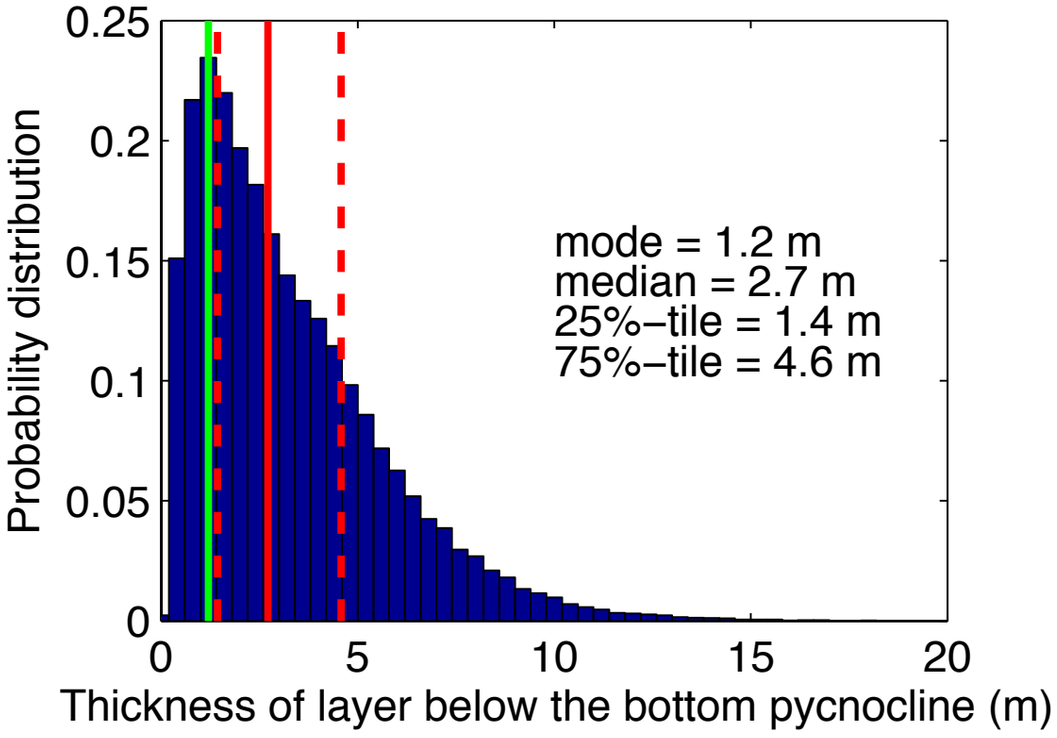

0.25
0.2
0.15
0.1
0.05
0
Probability distribution
0
5
10
15
20
Thickness of layer below the bottom pycnocline (m)
mode = 1.2 m
median = 2.7 m
25%–tile = 1.4 m
75%–tile = 4.6 m


0.25
0.2
0.15
0.1
0.05
0
Probability distribution
mode = 2 m
median = 2.6 m
25%–tile = 1.6 m
75%–tile = 4.1 m
0
5
10
15
20
Thickness of hypoxic layer above bottom (m)


0.25
0.2
0.15
0.1
0.05
0
Probability distribution
mode = 1.2 m
median = 2.7 m
25%–tile = 1.4 m
75%–tile = 4.6 m
0
5
10
15
20
Thickness of layer below the bottom pycnocline (m)


Kemp et al. MEPS (1992)
60%
50%
40%
30%
20%
10%
0%
SOC:TR
Murrell & Lehrter (2011)
0
20
40
60
Bottom Depth (m)

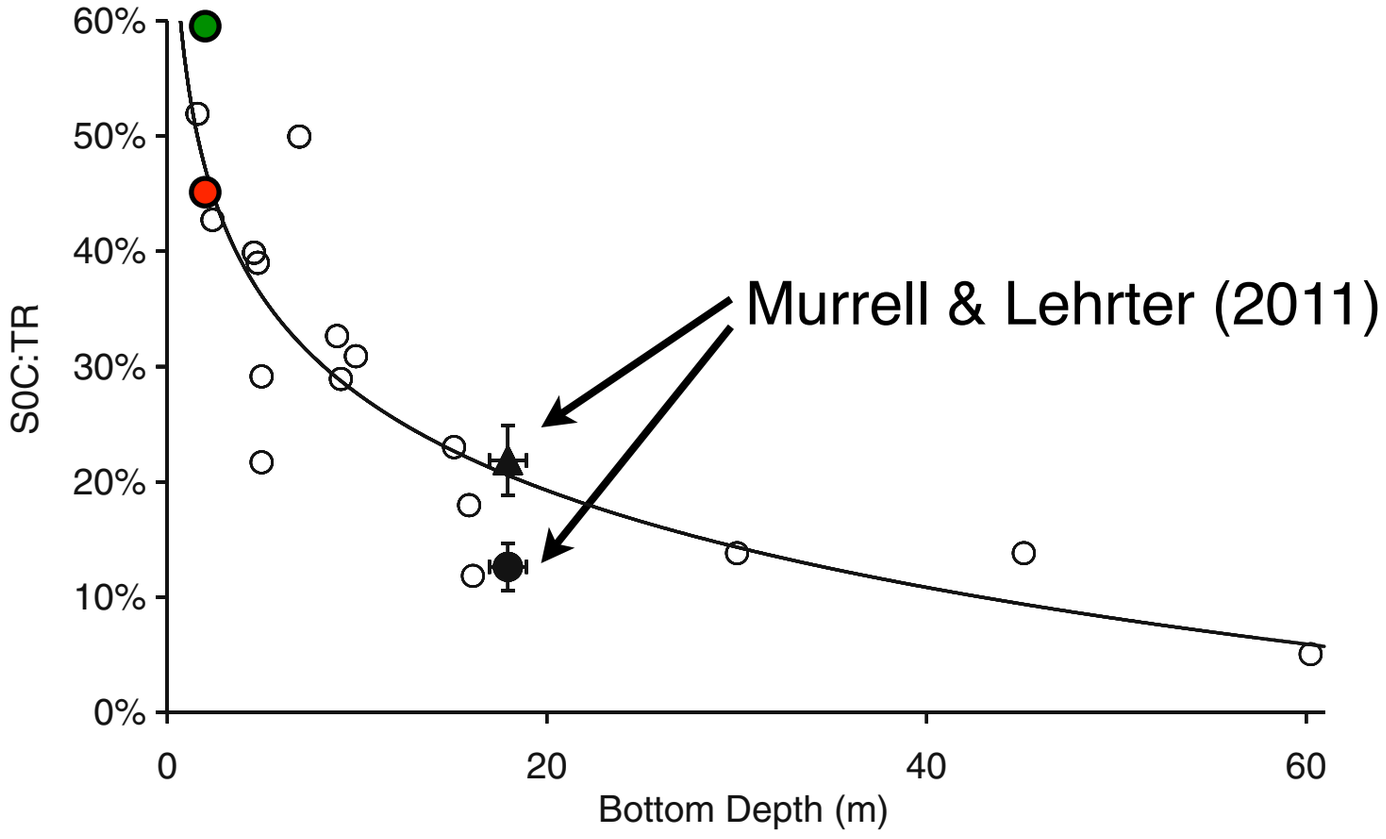


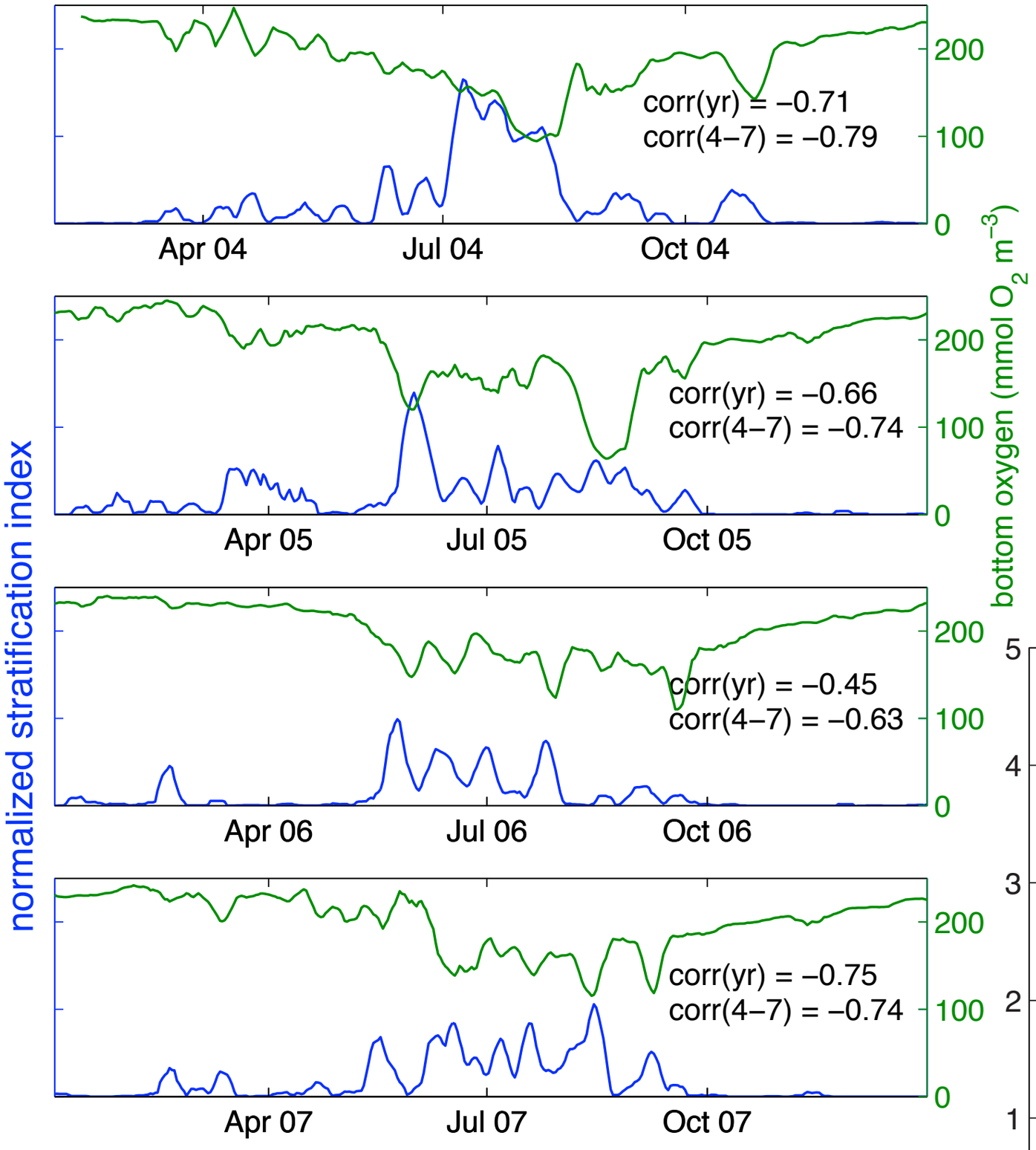


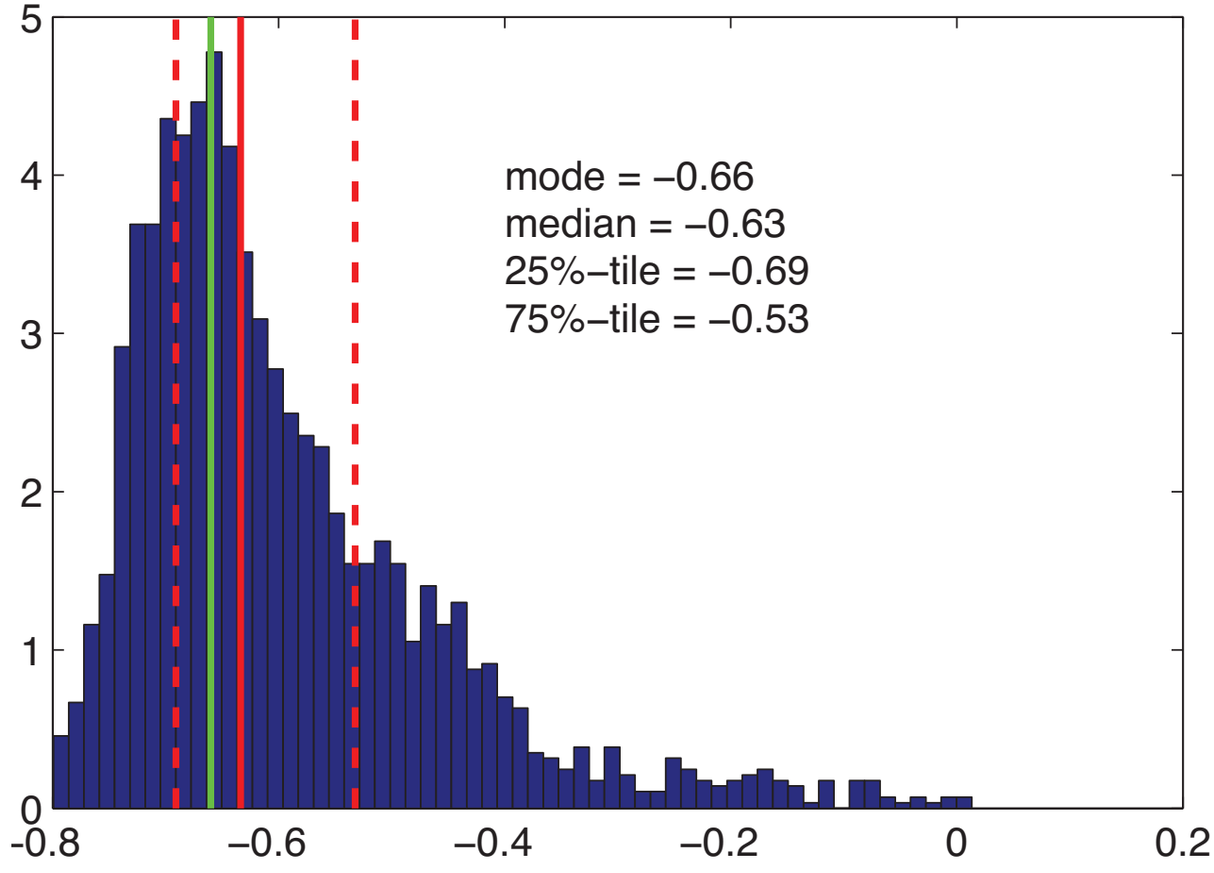
WR and SOC from M&L, 2 m BBL

WR from M&L, SOC from Rowe et al. (2002)

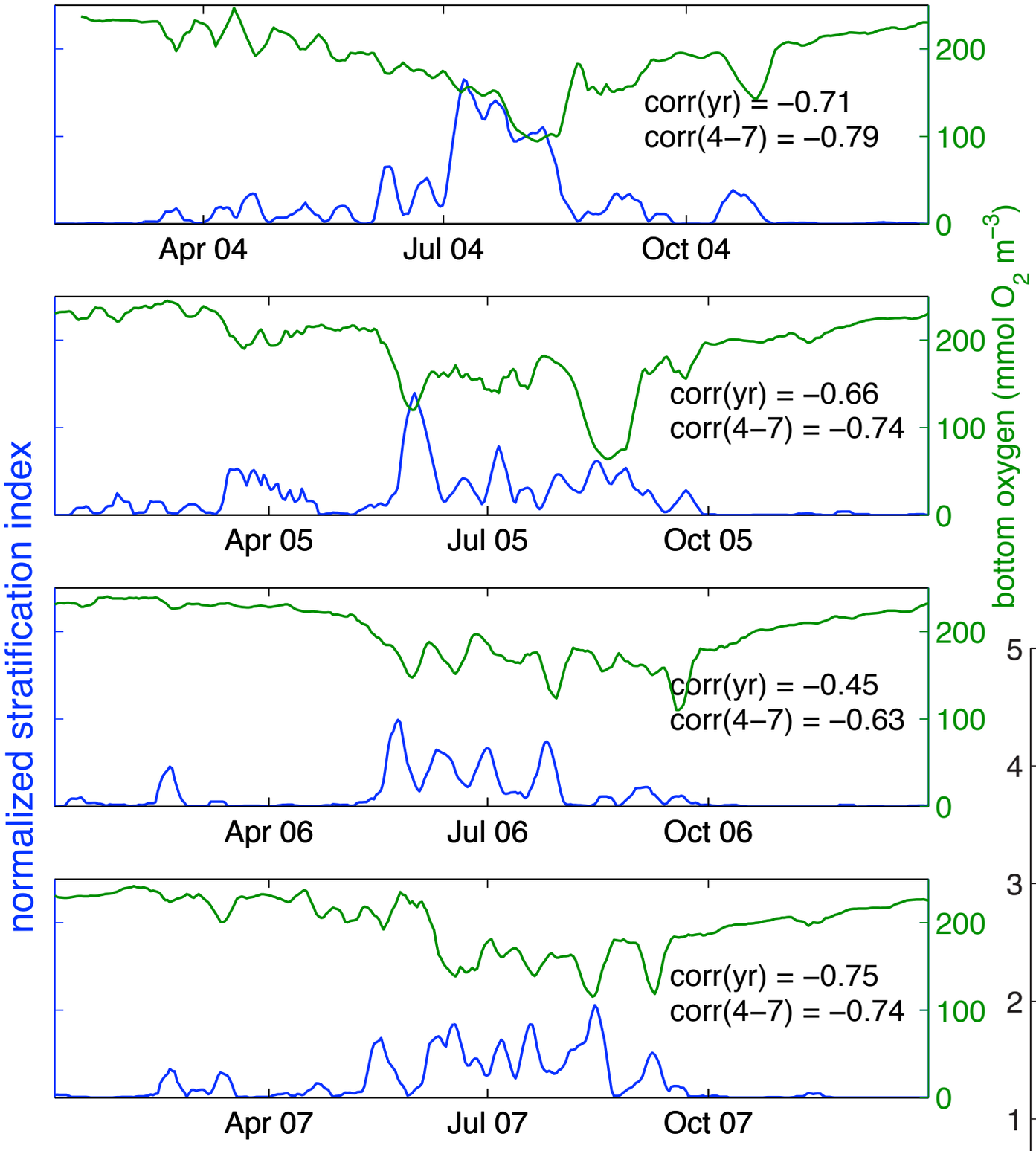
Kemp et al. MEPS (1992)



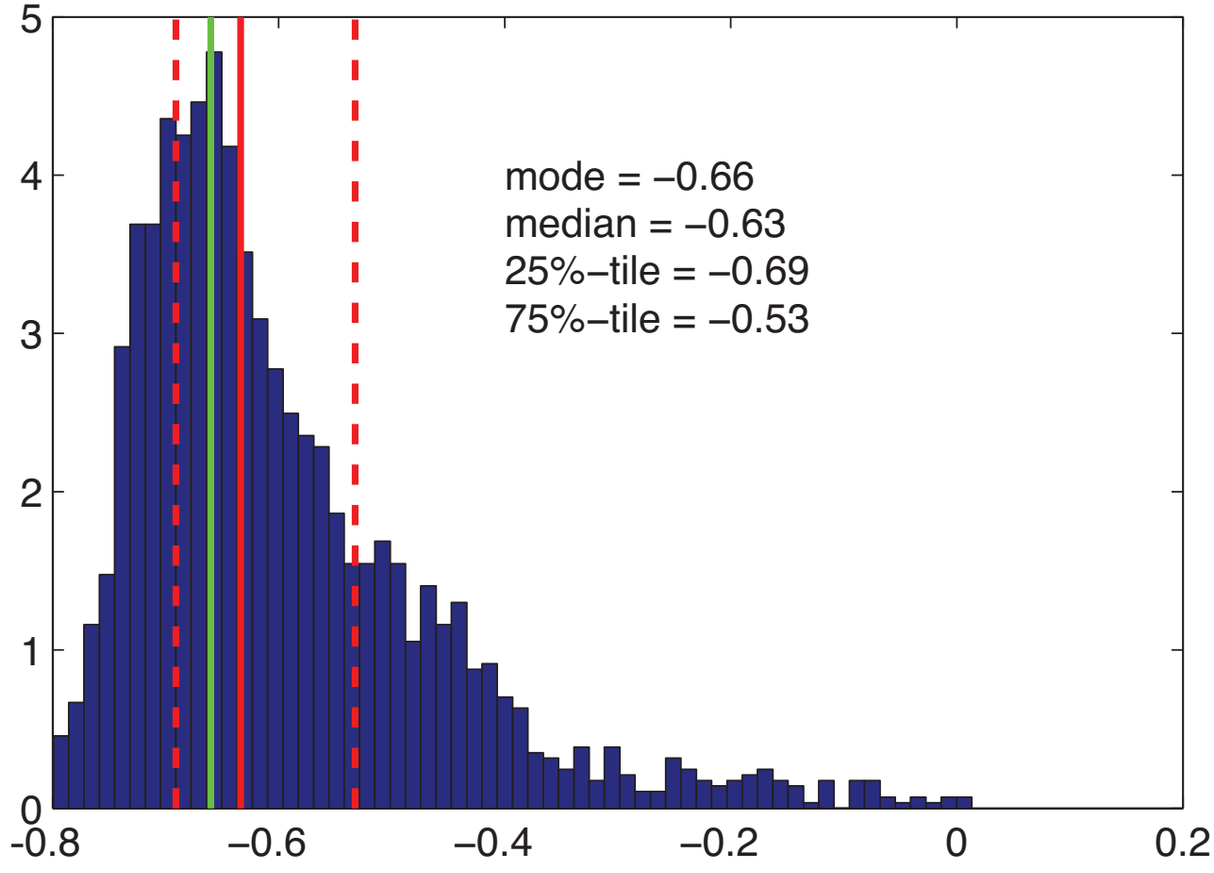




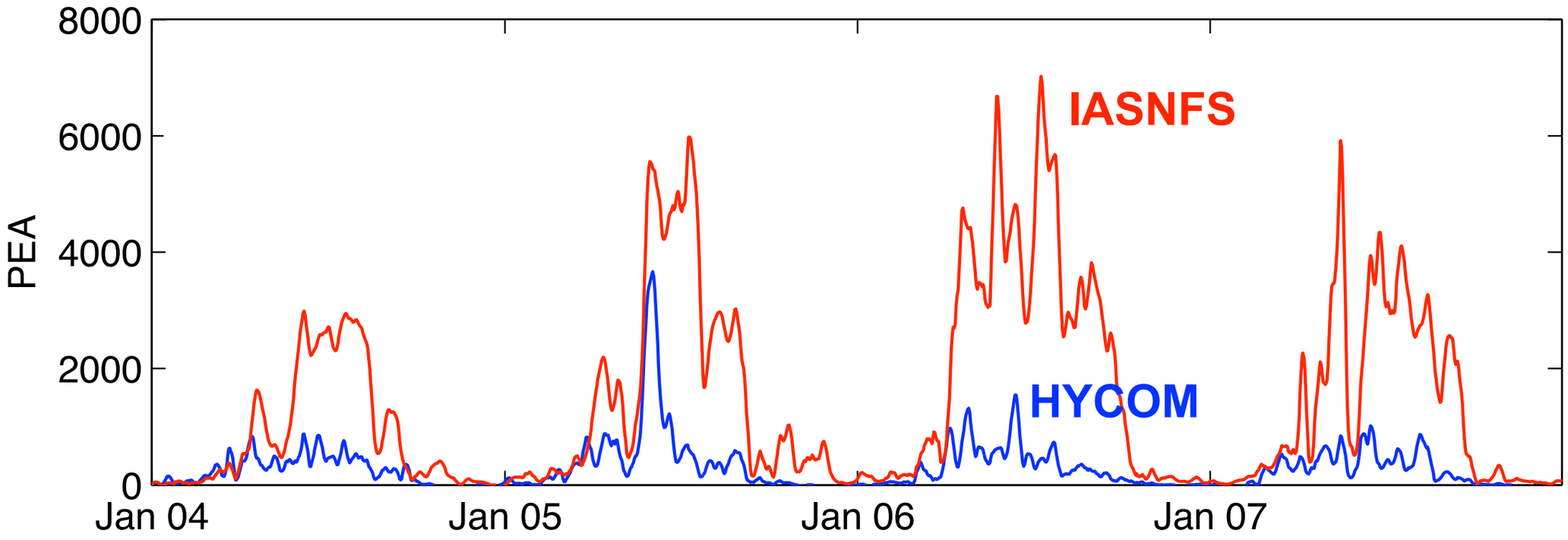
PDF of temporal correlation between stratification index and bottom oxygen

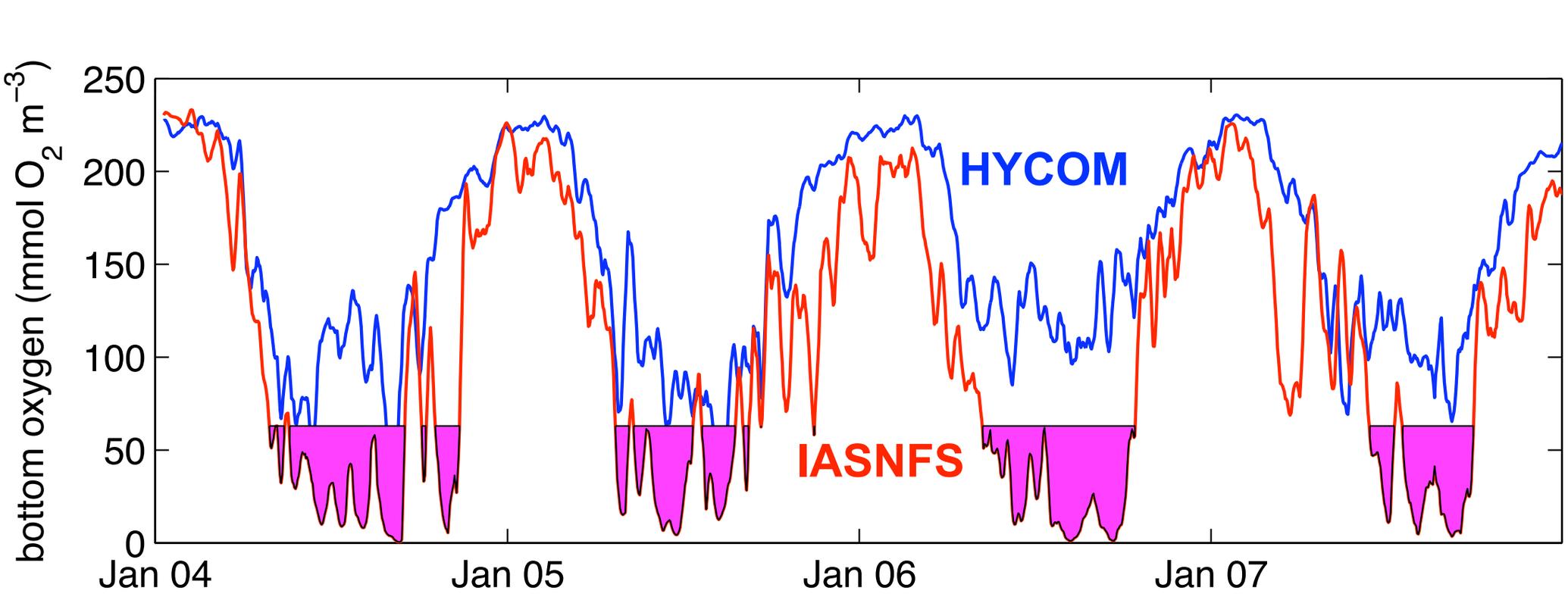


Can this explain differences between B30HYC and B30IAS?



PDF of temporal correlation between stratification index and bottom oxygen


8000
6000
4000
2000
0
PEA
IASNFS
HYCOM
Jan 04
Jan 05
Jan 06
Jan 07


250
200
150
100
50
0
bottom oxygen (mmol O2 m−3)
HYCOM
IASNFS
Jan 04
Jan 05
Jan 06
Jan 07

Conclusions

Hypoxia predictions are very sensitive to the parameterization of SOC.

Results because hypoxic conditions are restricted to a relatively thin layer above the bottom over most of the shelf.

Strength of vertical stratification is an important predictor of oxygen in bottom waters.

Modification of physical horizontal boundary conditions can have a large effect on hypoxia predictions.

COMT SH: Seasonal and short-term forecasting system for hypoxia and nutrient load scenarios

PIs: K. Fennel (Dal), R. Hetland (TAMU), J. Xu (NOAA CSDL), D.S. Ko (NRL) **Partners:** F. Aikman (NOAA CSDL), J. Lehrter & M. Murrell (EPA)

Three models: ROMS, FVCOM & NCOM (physics already run operationally or perpetually; all w/ hypoxia module)

1. model intercomparison
2. large model ensemble (O(100)) representing different atmospheric and river forcing conditions and nutrient loads
3. probabilistic seasonal hypoxia forecasts & nutrient reduction effects
4. short-term forecasts (O(days)) prior to monitoring cruises