Primary processes controlling oxygen dynamics on the Texas-Louisiana Shelf

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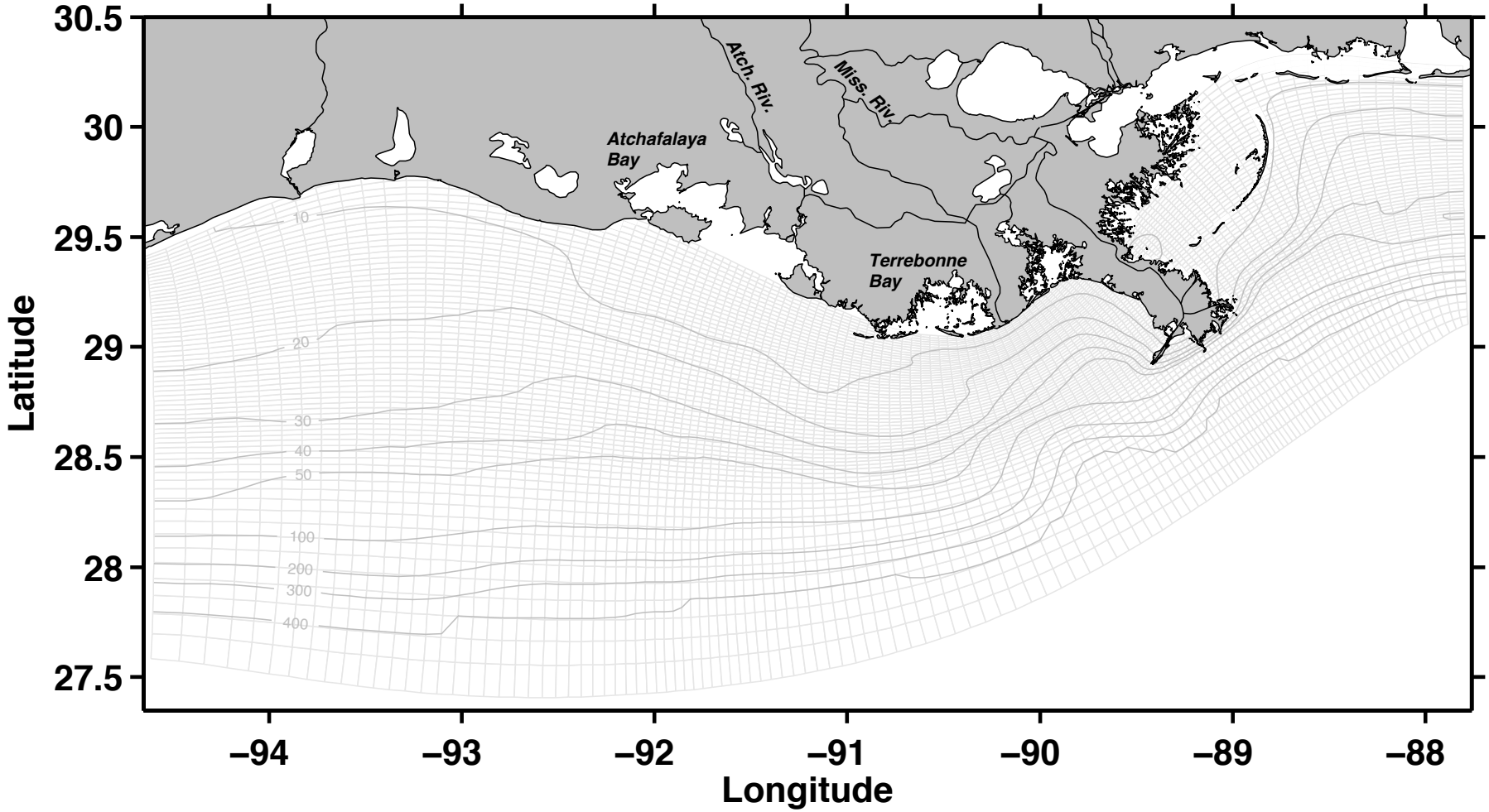
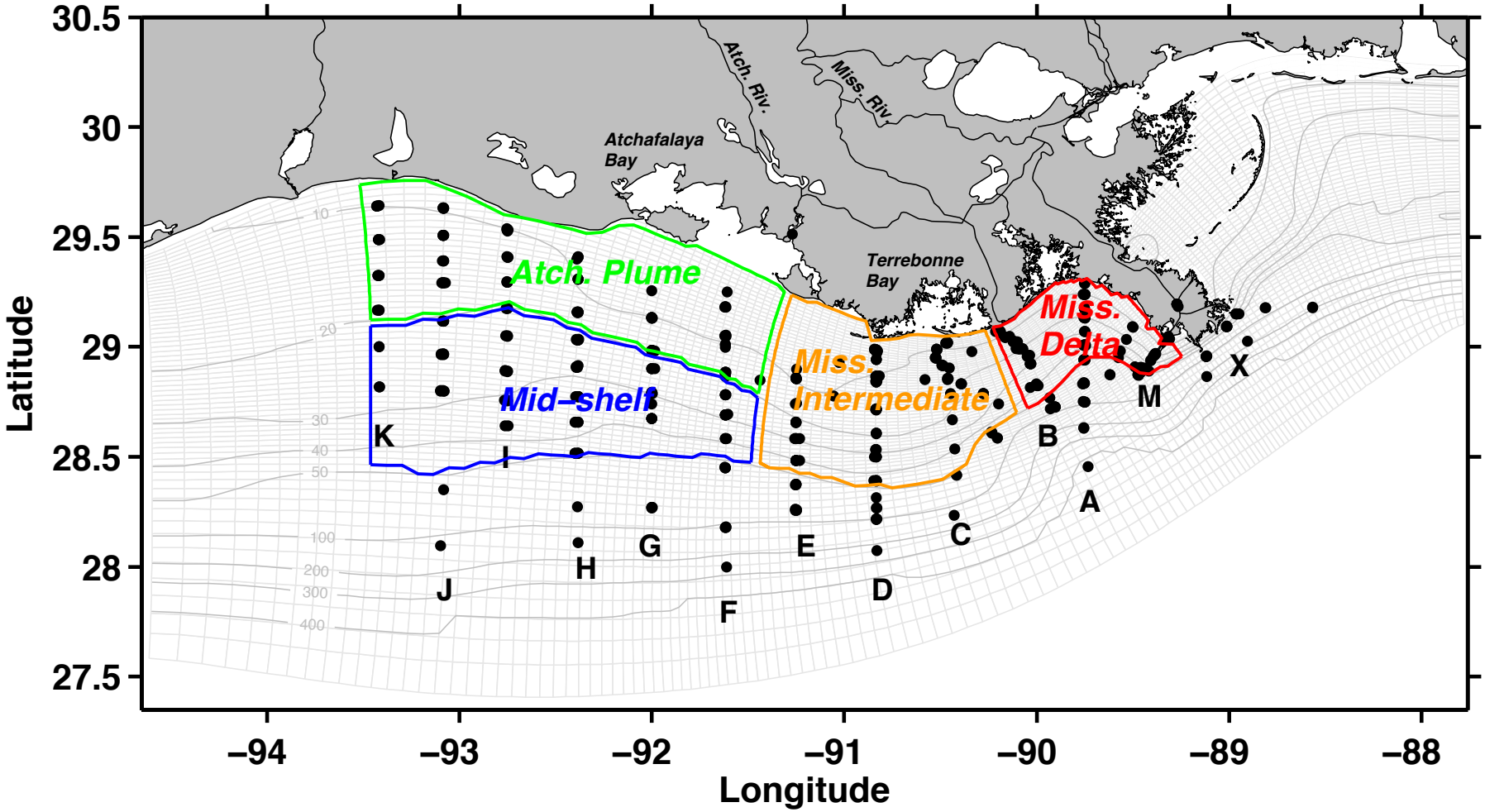
Model description



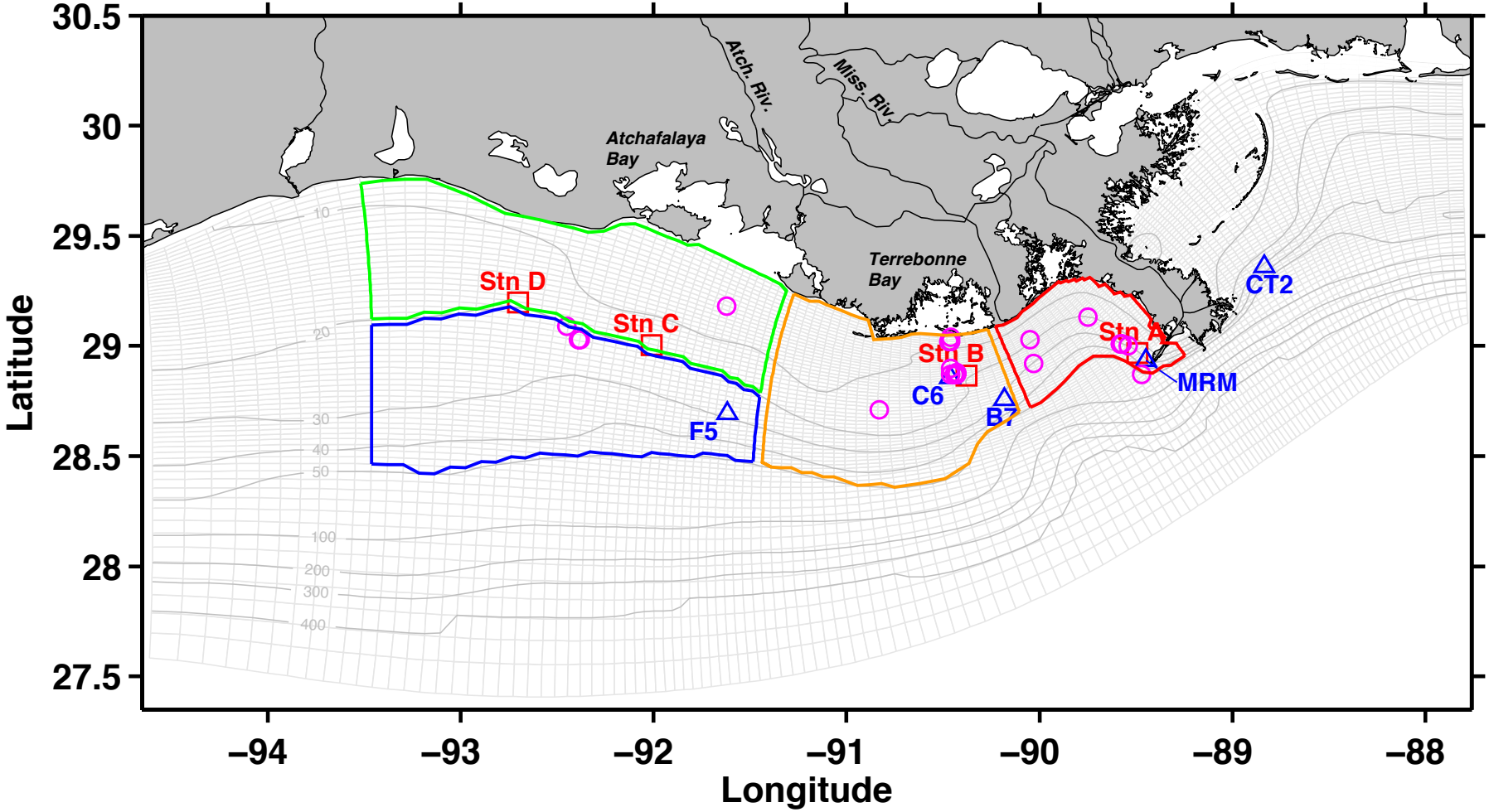
Circulation Model: Regional Ocean Modeling System (ROMS)
Resolution: 20 layers in vertical; 1 km ~ 20 km in horizontal
Horizontal boundary condition: Climatological
Simulation period: 1 February, 2004 to 29 December 2009

Model description



- Primary production (PP) data from Lehrter et al. (2009)
  Water column respiration (WR) data from Murrell et al. (2013)

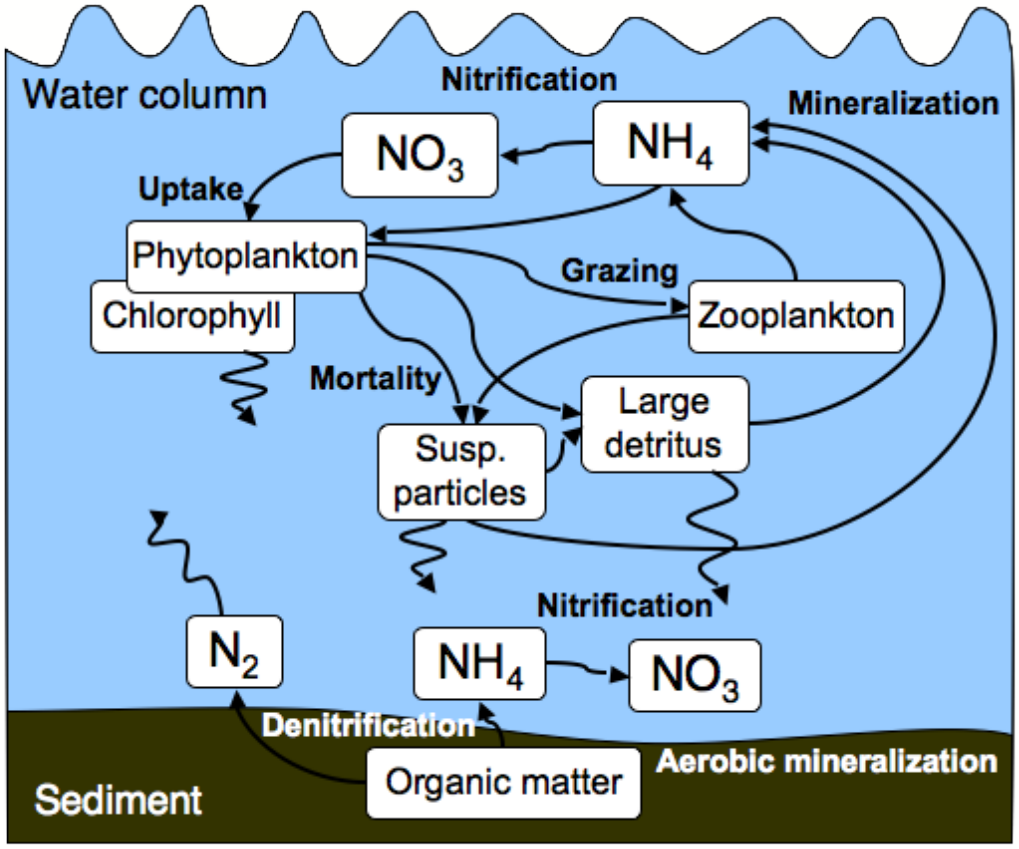
Model description

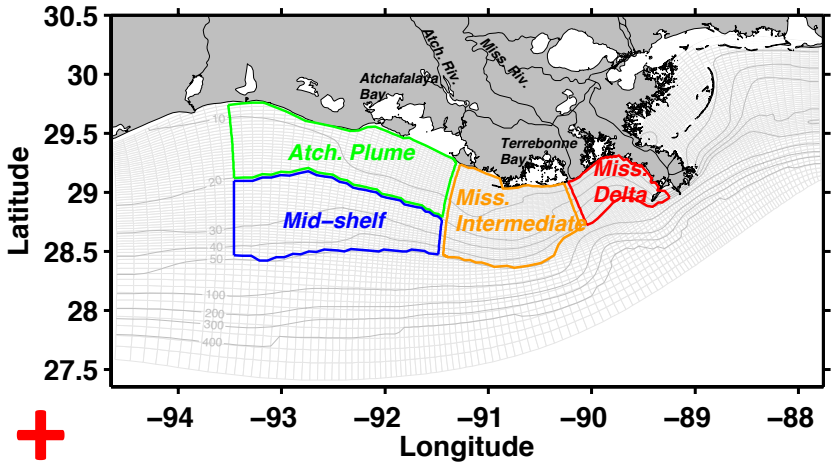


Benthic data from:

○ Lehrter et al. 2012 □ Nunally et al. 2013 △ McCarthy et al. 2013

Model description



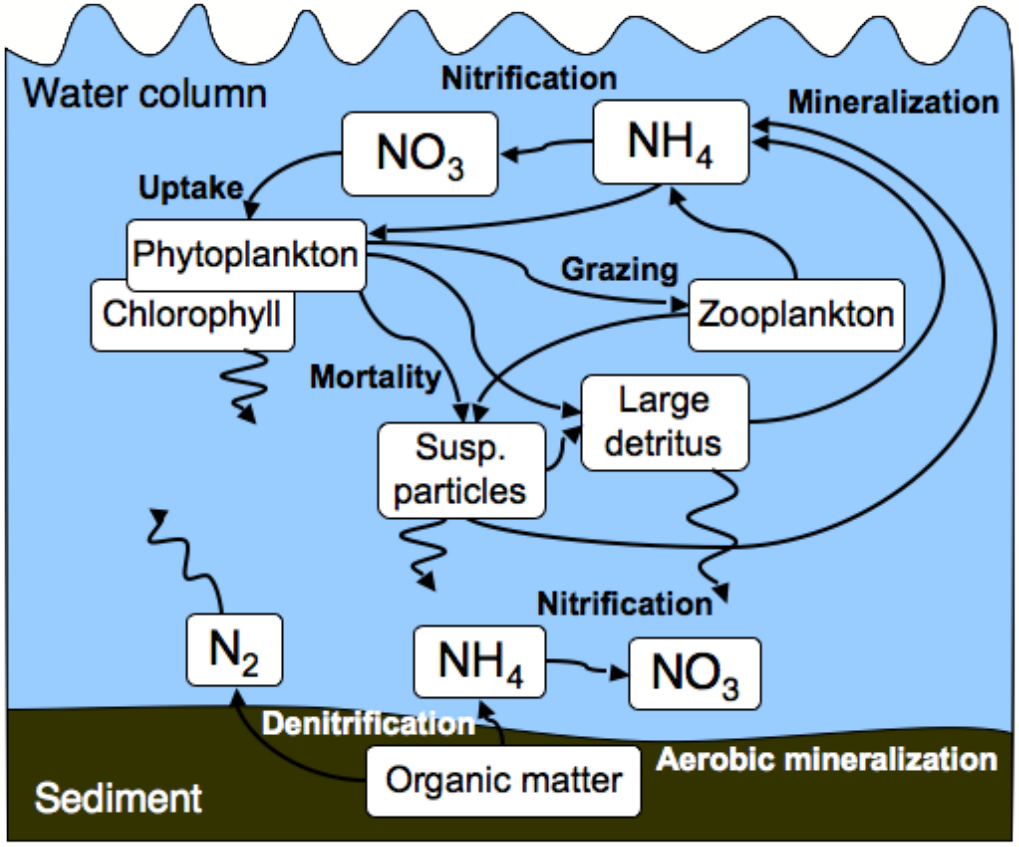


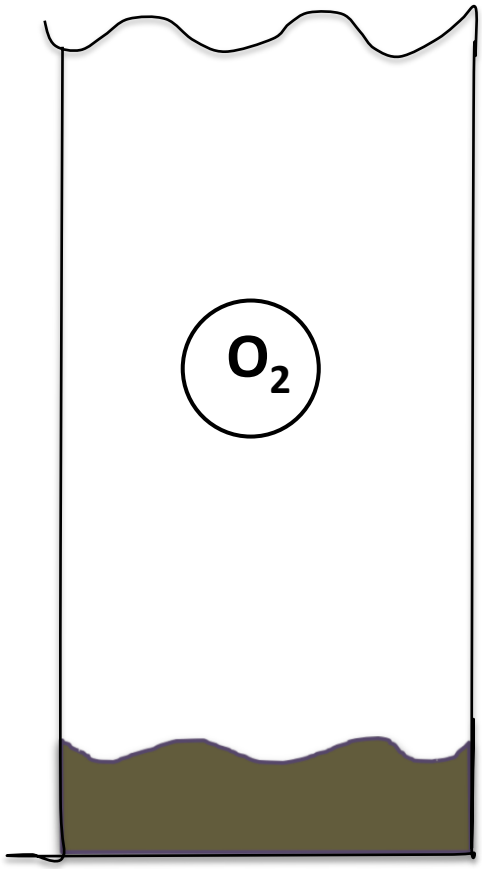
Fennel et al. 2006, 2011

2 different parameterizations for **sediment oxygen consumption (SOC)**:

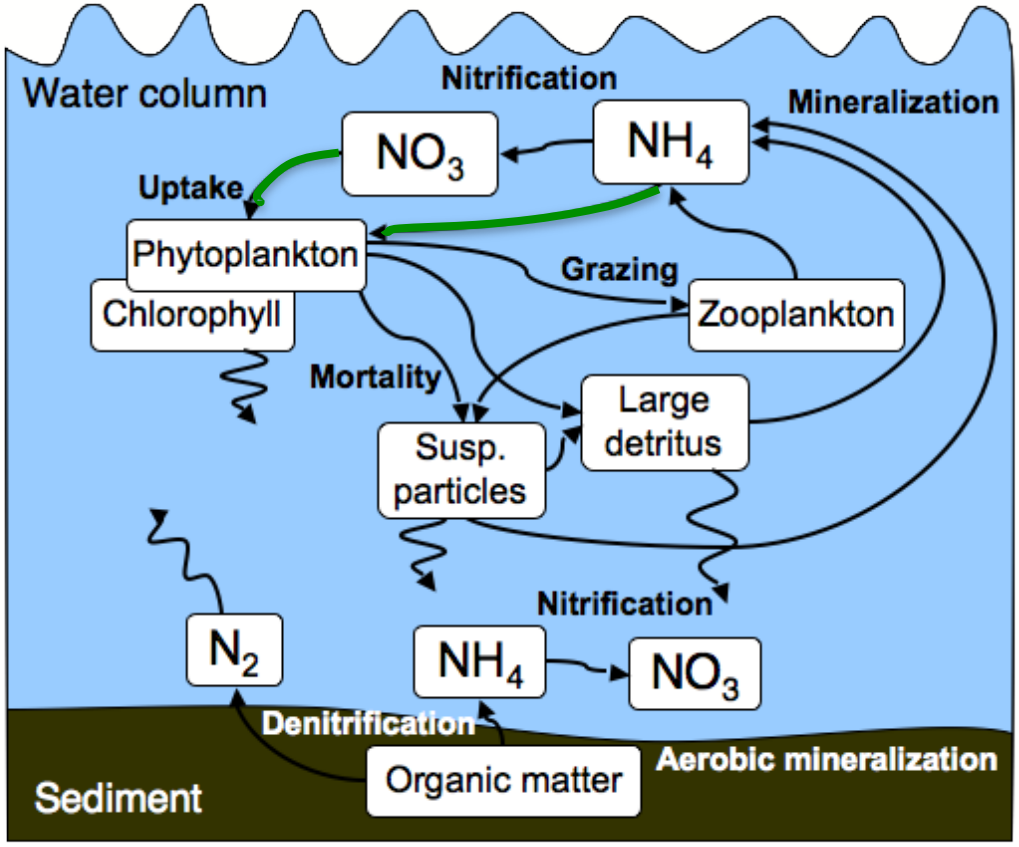
- **IR**: Organic matter reaching sediment are **instantaneously remineralized.**
- **H&D**: Hetland and DiMarco (2008) $SOC = 6.0 * 2^{T/10} * (1\text{-}exp(DO/30))$

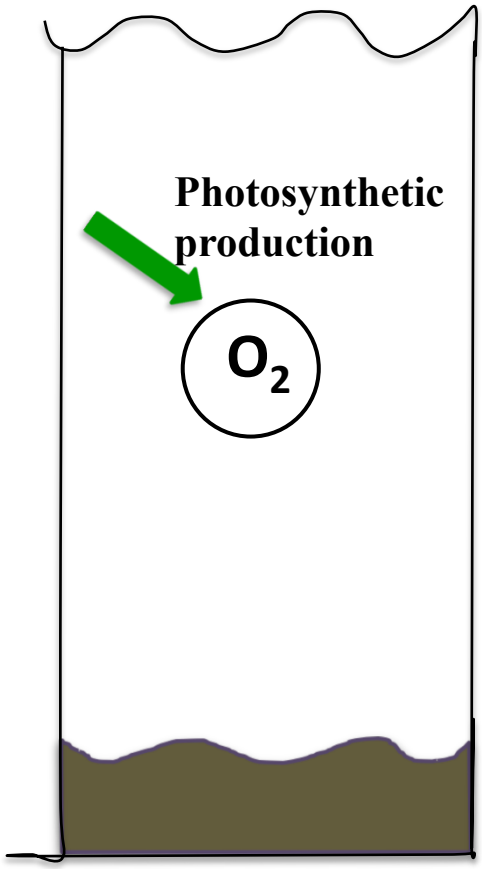
Model description





Model description

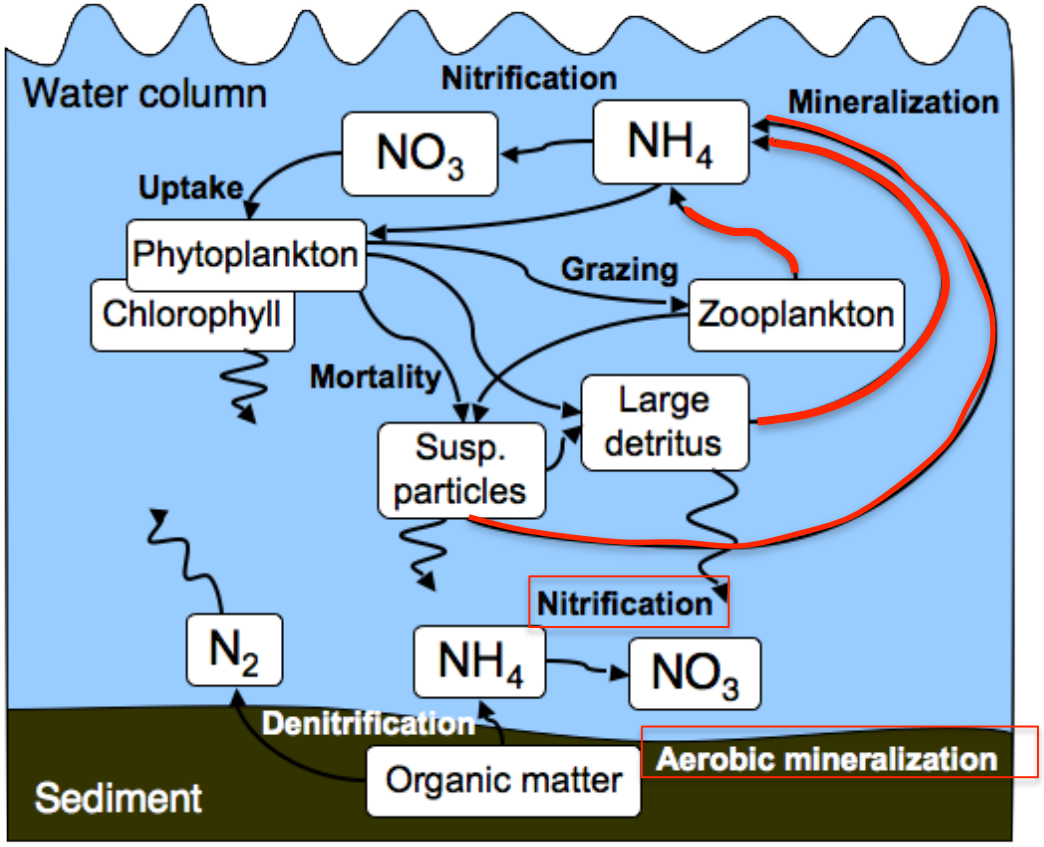


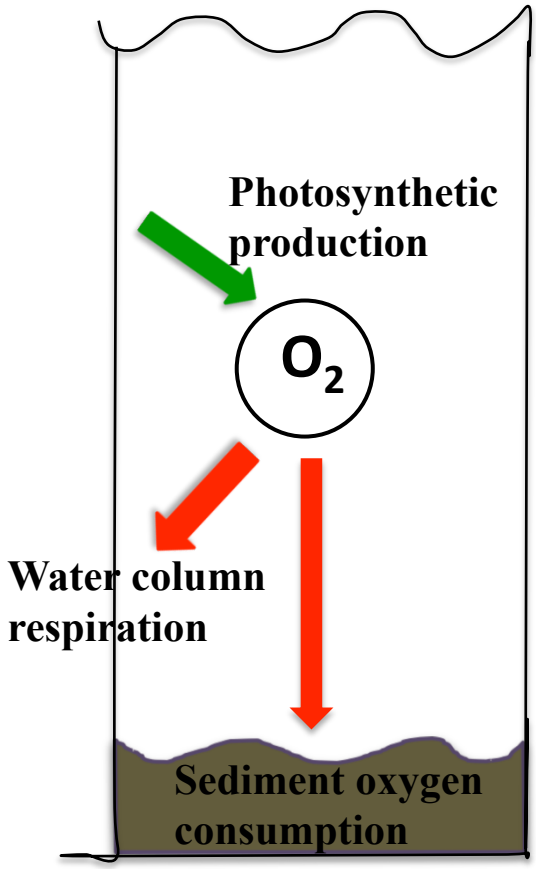


Biological processes:

Photosynthetic production (PP) → O_2 source

Model description





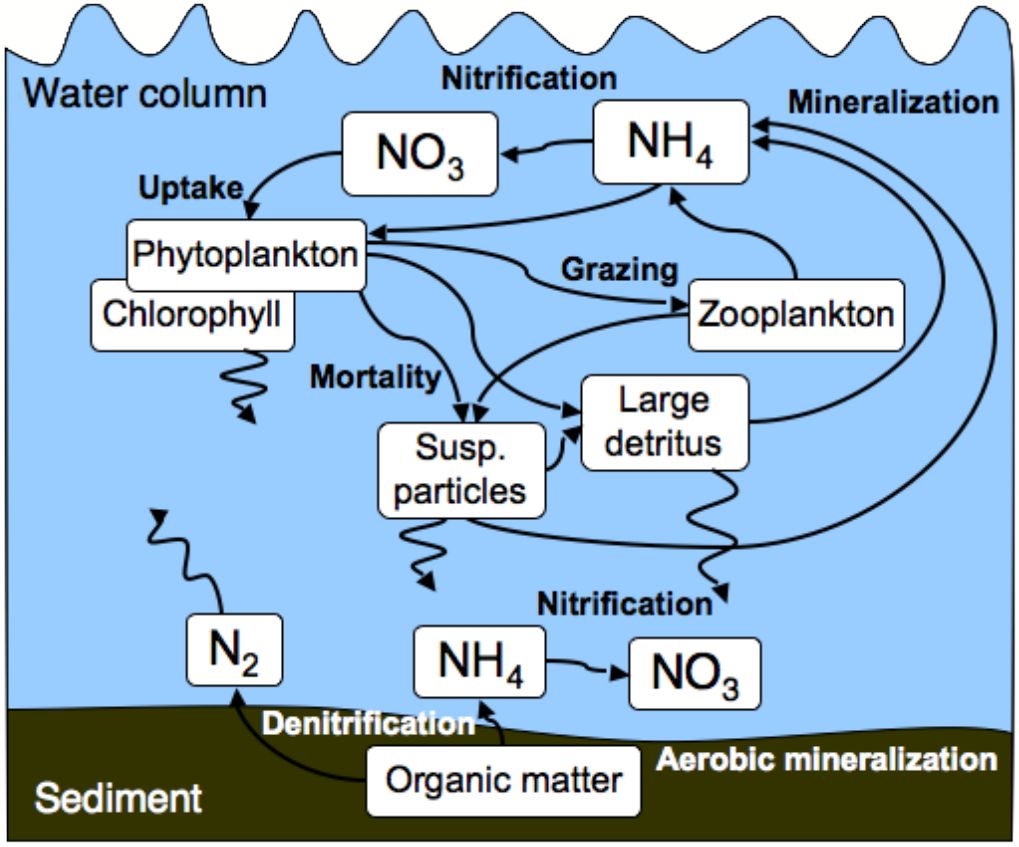
Biological processes:

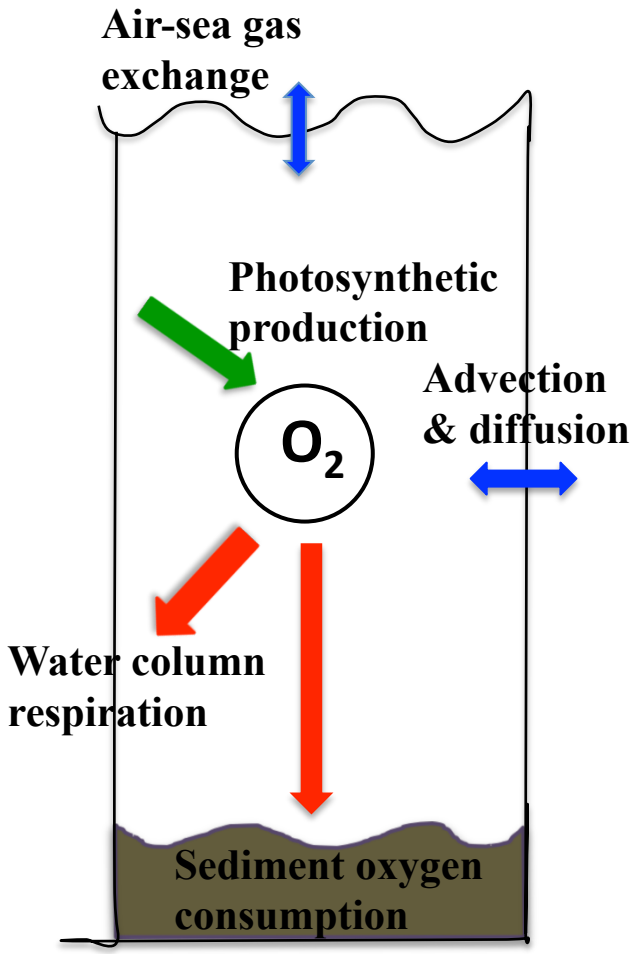
Photosynthetic production (PP) → O_2 source

O_2 sinks ←

Water column respiration (WR); Sediment oxygen consumption (SOC)

Model description





Biological processes:

Photosynthetic production (PP) → O_2 source

O_2 sinks ←

Water column respiration (WR); Sediment oxygen consumption (SOC)

Physical processes:

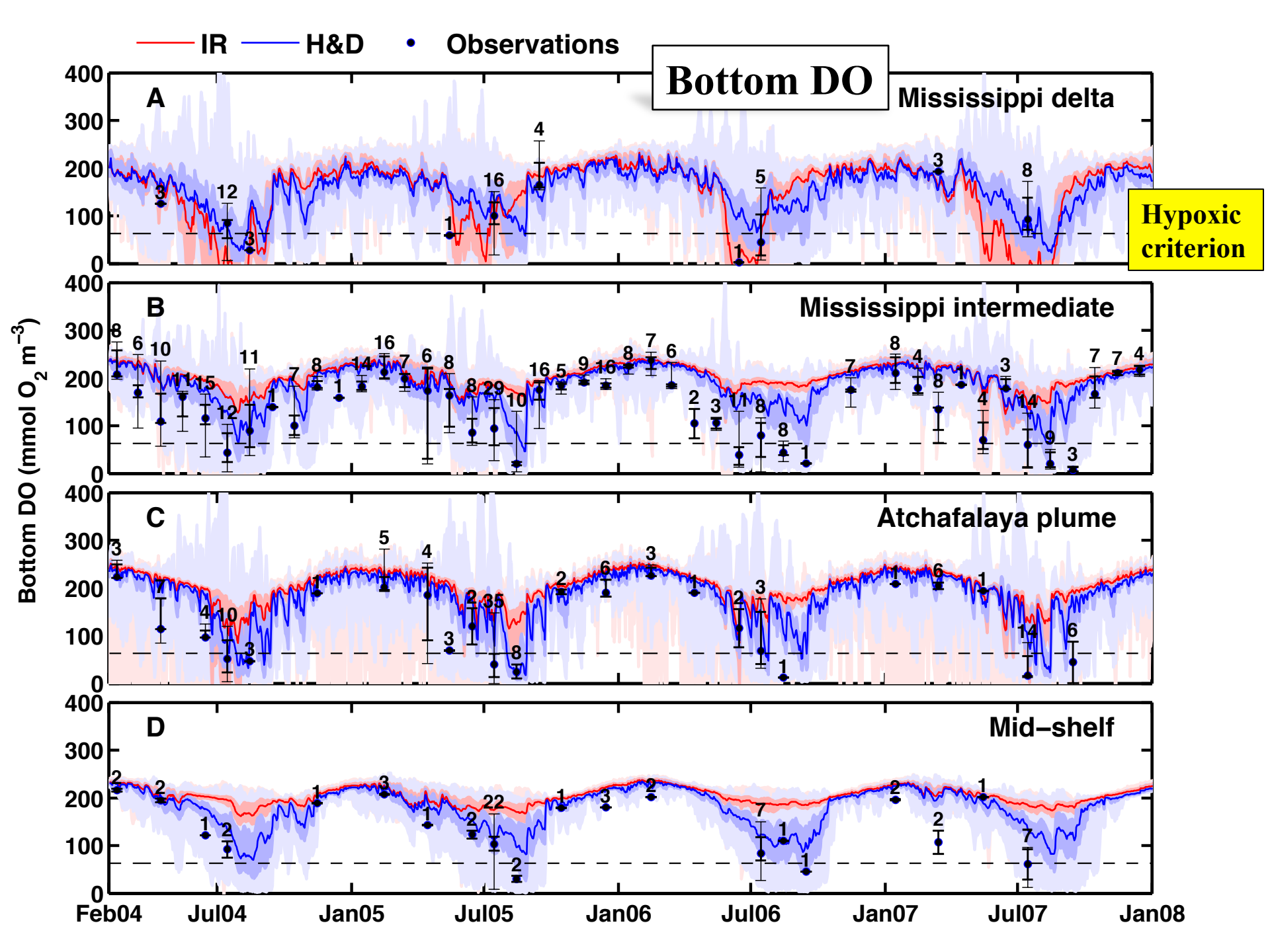
Air-sea gas exchange; Advection and diffusion → O_2 source or sink

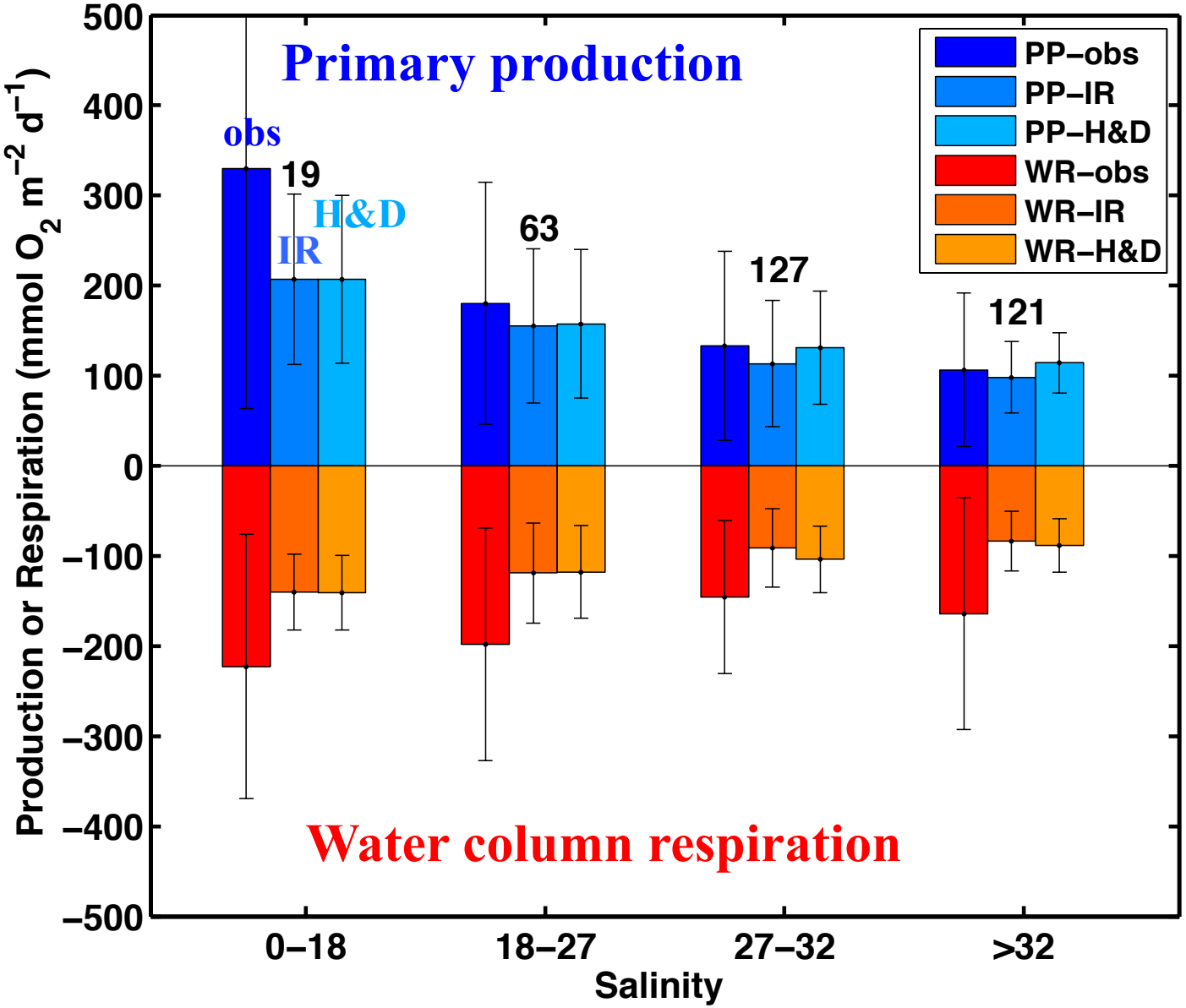
Objective

✧ Investigate the spatial and temporal variations in oxygen dynamics across the Texas-Louisiana shelf

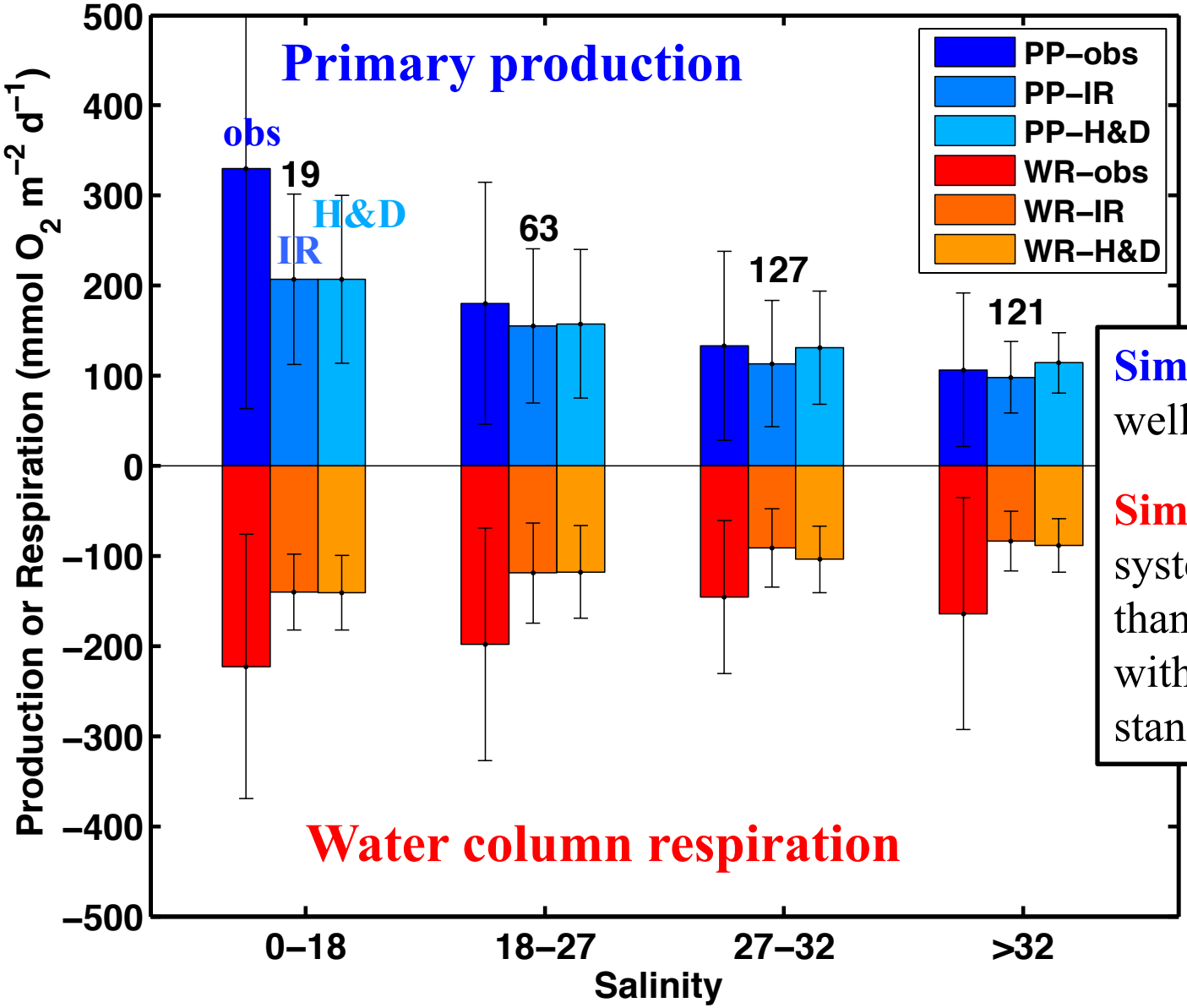
✧ Estimate the relative magnitude of each oxygen source and sink in regulating bottom water hypoxia

- Compare with available observations of DO, PP, WR and SOC;
- Calculate oxygen budgets in selected stations.


IR
H&D
Observations
Bottom DO
A
Mississippi delta
B
Mississippi intermediate
C
Atchafalaya plume
D
Mid–shelf
Hypoxic criterion
Bottom DO (mmol O2 m-3)
0
100
200
300
400
Feb04
Jul04
Jan05
Jul05
Jan06
Jul06
Jan07
Jul07
Jan08



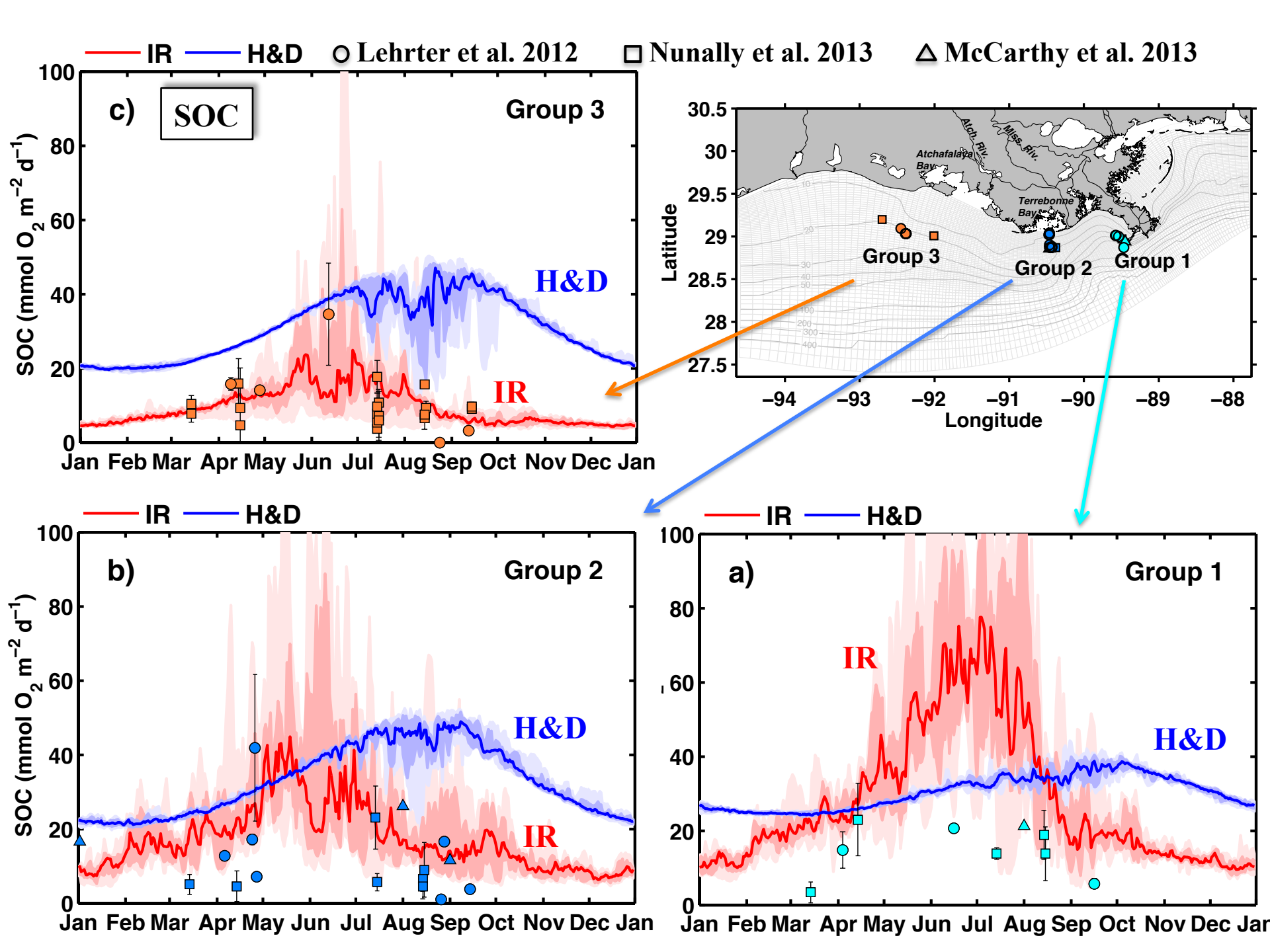
PP from Lehrter et al. (2009) and WR from Murrell et al. (2013)



Simulated PP agrees well with observations

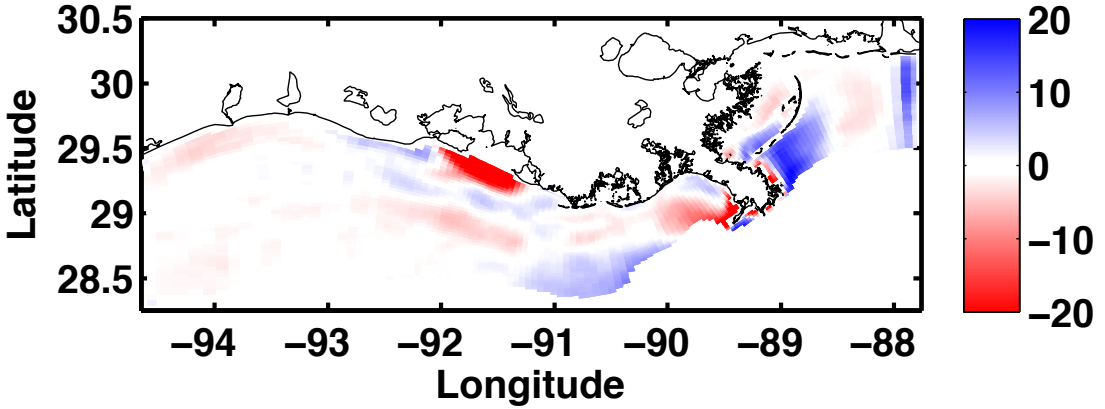
Simulated WR is systematically lower than observations, but within the observed standard deviations.

PP from Lehrter et al. (2009) and WR from Murrell et al. (2013)


IR
H&D
Lehrter et al. 2012
Nunally et al. 2013
McCarthy et al. 2013
c)
SOC
Group 3
SOC (mmol O2 m-2 d-1)
H&D
IR
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Latitude
Longitude
Atchafalaya Bay
Atch. Riv.
Miss. Riv.
Terrebonne Bay
Group 3
Group 2
Group 1
b)
Group 2
a)
Group 1

IR

Production – Total respiration (mol O_2 m^{-2} y^{-1})

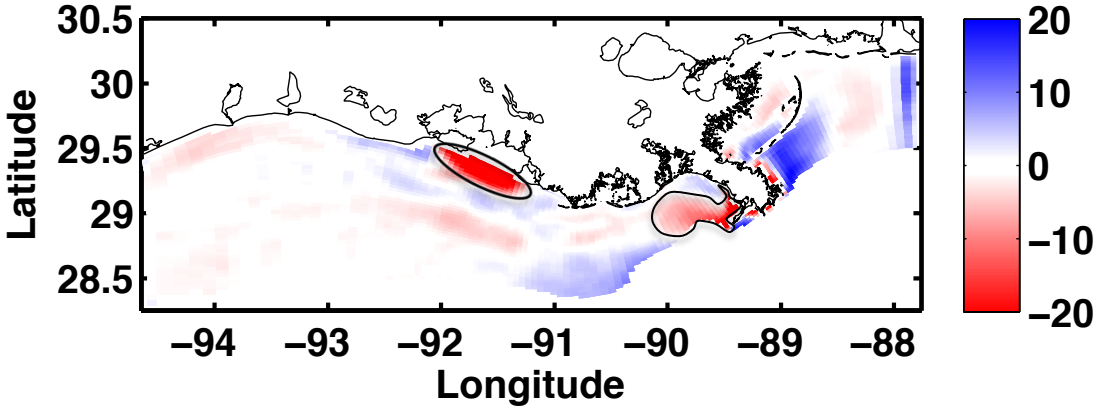


> 0: Autotrophic

< 0: Heterotrophic

IR

Production – Total respiration (mol O_2 m^{-2} y^{-1})



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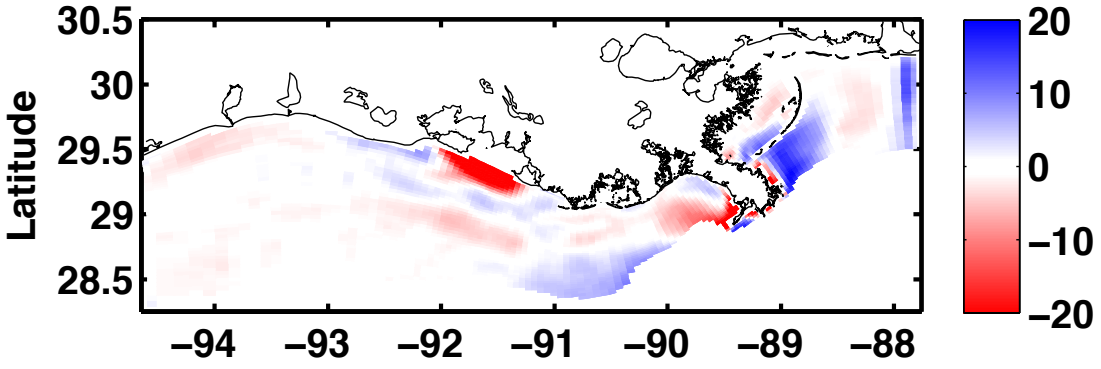
< 0: Heterotrophic

IR

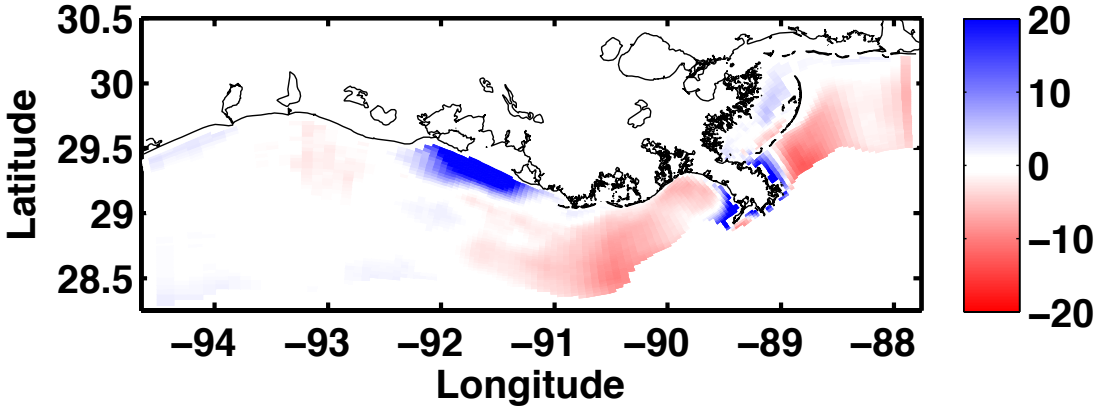
Production – Total respiration (mol O_2 m^{-2} y^{-1})



> 0: Autotrophic

< 0: Heterotrophic

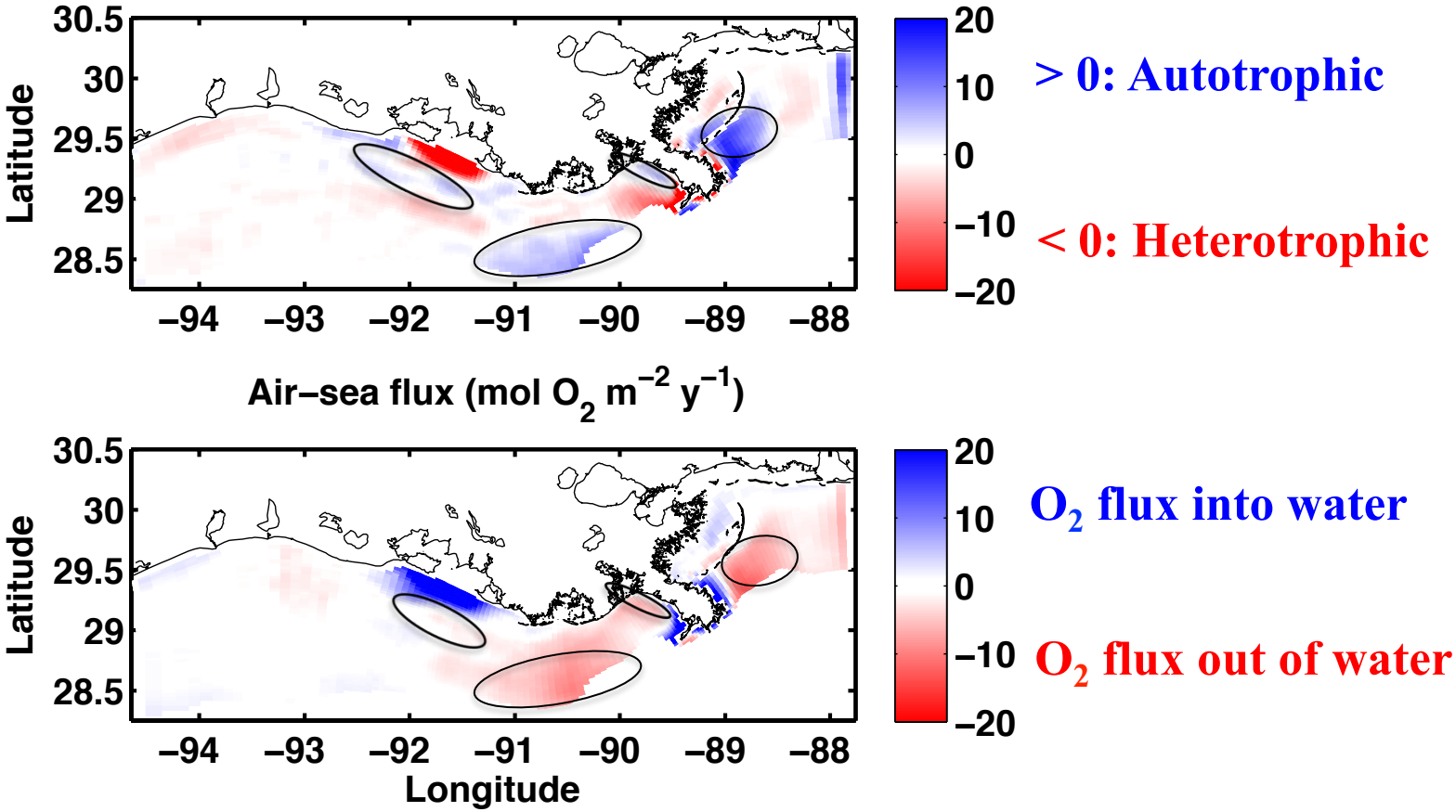
Air–sea flux (mol O_2 m^{-2} y^{-1})



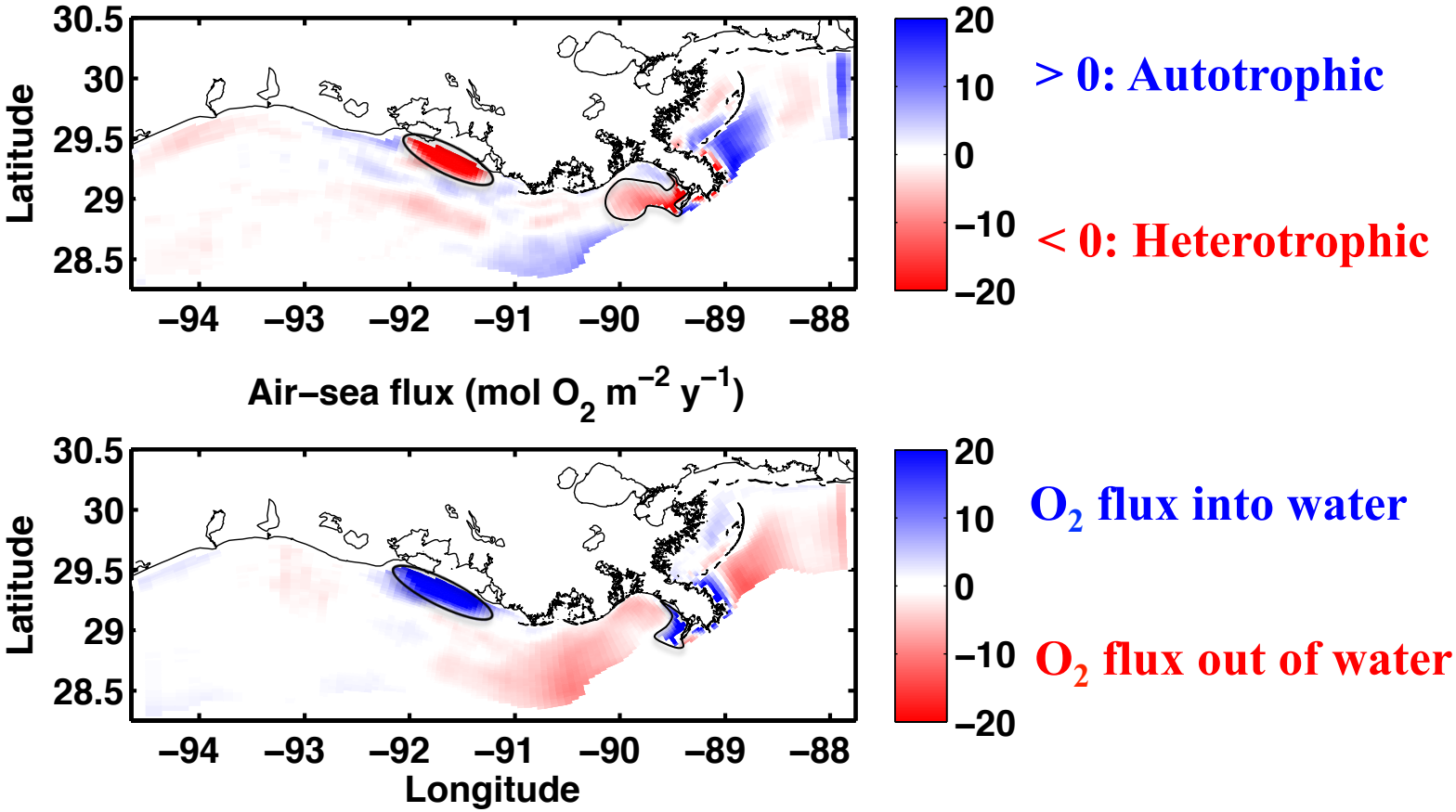
O_2 flux into water

O_2 flux out of water

IR


Production – Total respiration (mol O2 m−2 y−1)
Latitude
30.5
30
29.5
29
28.5
−94
−93
−92
−91
−90
−89
−88
20
10
0
−10
−20
> 0: Autotrophic
< 0: Heterotrophic
Air–sea flux (mol O2 m−2 y−1)
Latitude
Longitude
O2 flux into water
O2 flux out of water

IR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Air–sea flux (mol O2 m−2 y−1)
Latitude
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O2 flux into water
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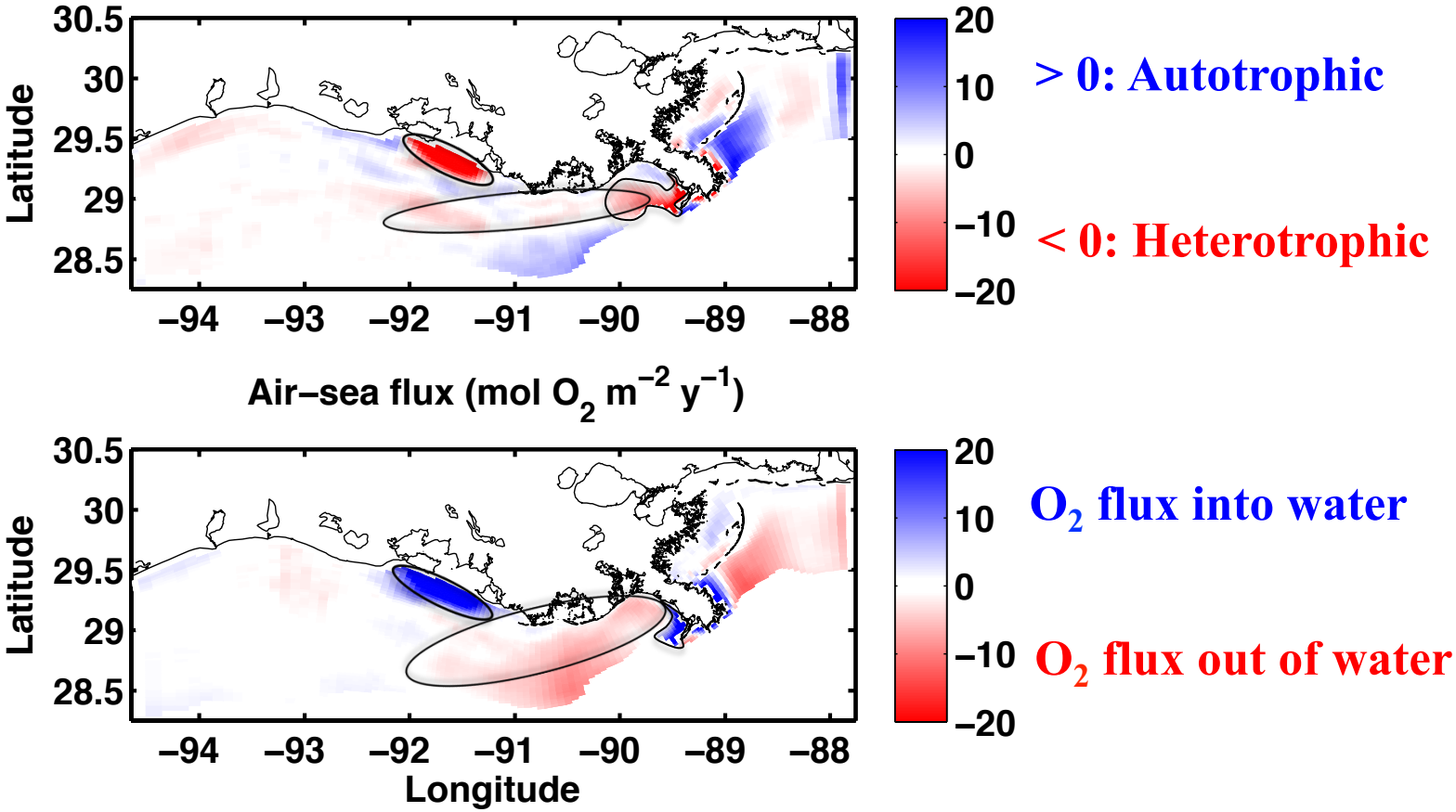
IR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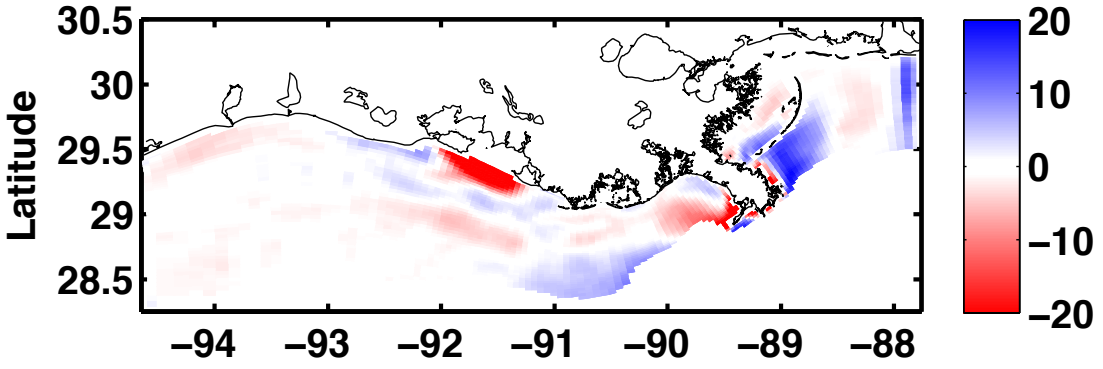
Air–sea flux (mol O2 m−2 y−1)
Latitude
Longitude
O2 flux into water
O2 flux out of water

IR

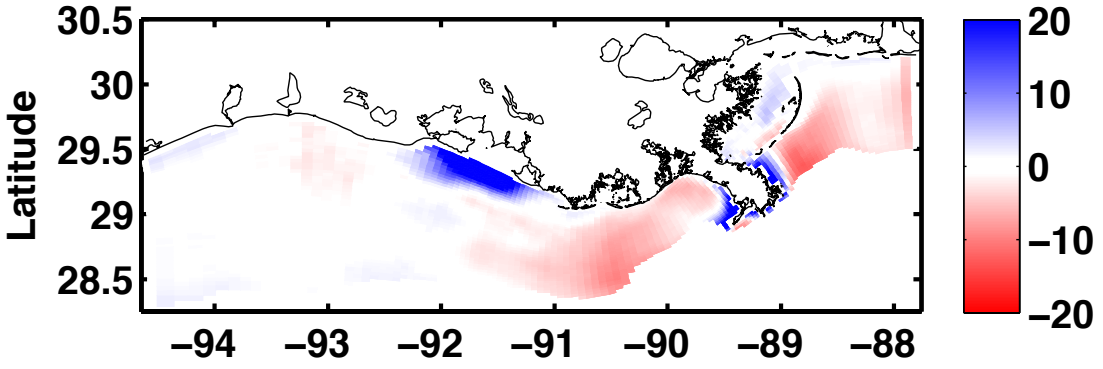
Production – Total respiration (mol O_2 m^{-2} y^{-1})



> 0: Autotrophic

< 0: Heterotrophic

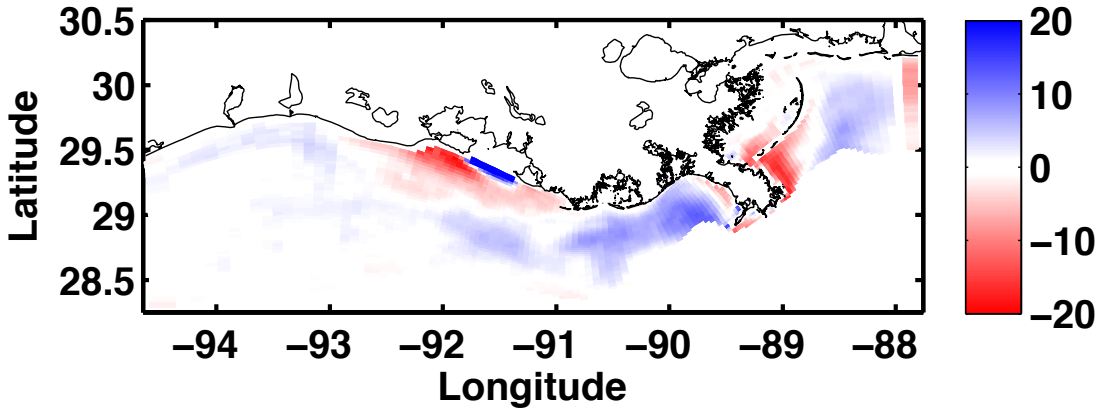
Air–sea flux (mol O_2 m^{-2} y^{-1})



O_2 flux into water

O_2 flux out of water

Advection & diffusion (mol O_2 m^{-2} y^{-1})

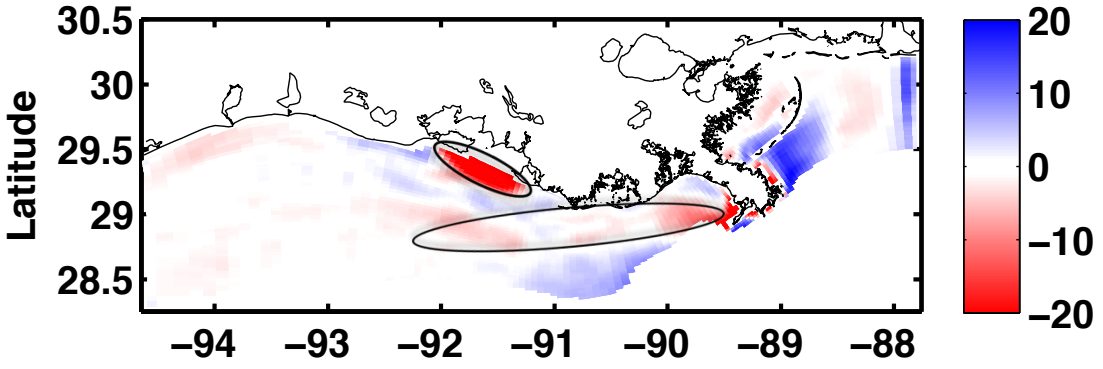


Transport O_2 in

Transport O_2 out

IR

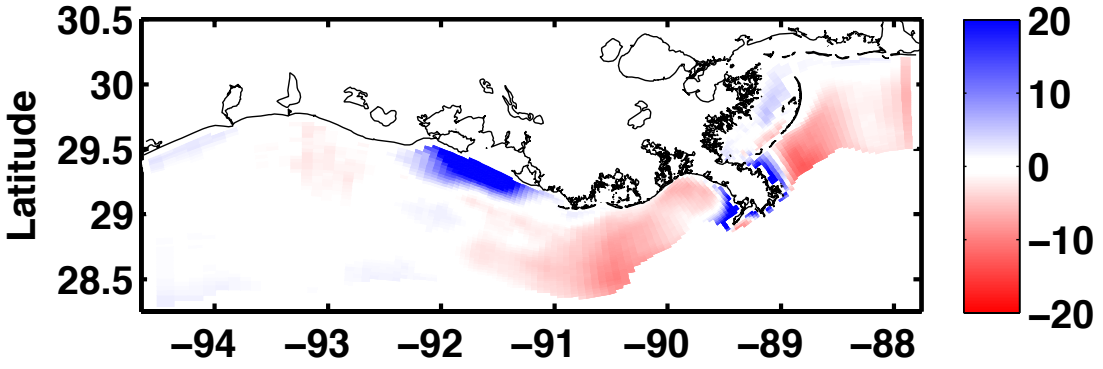
Production – Total respiration (mol O_2 m^{-2} y^{-1})



> 0: Autotrophic

< 0: Heterotrophic

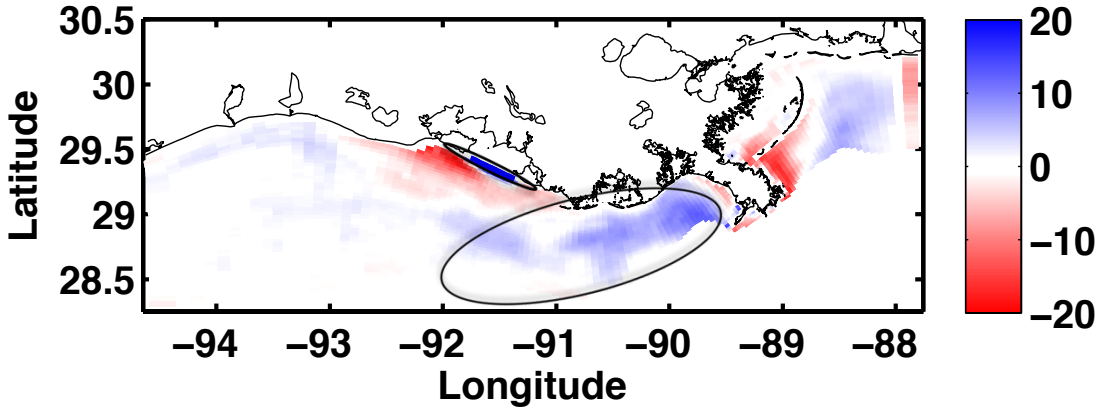
Air–sea flux (mol O_2 m^{-2} y^{-1})



O_2 flux into water

O_2 flux out of water

Advection & diffusion (mol O_2 m^{-2} y^{-1})

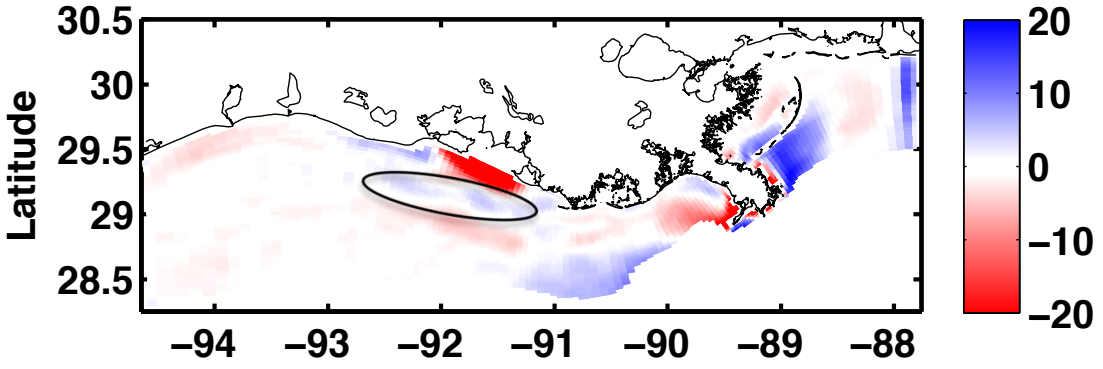


Transport O_2 in

Transport O_2 out

IR

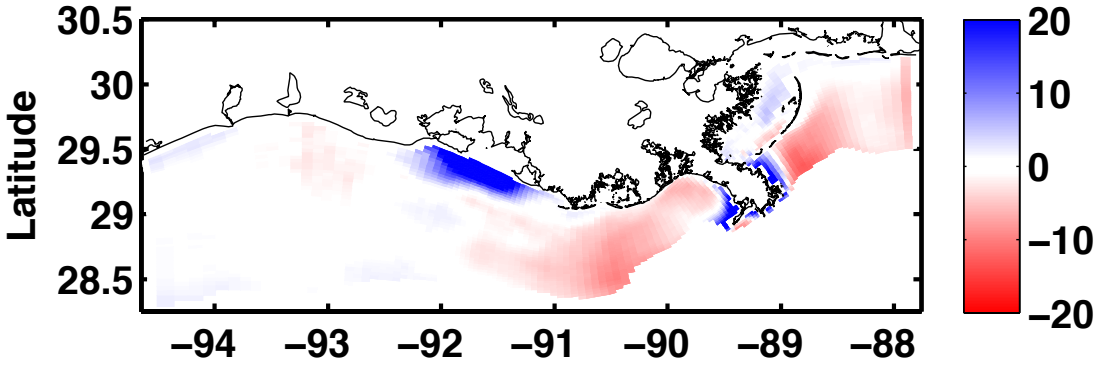
Production – Total respiration (mol O_2 m^{-2} y^{-1})



> 0: Autotrophic

< 0: Heterotrophic

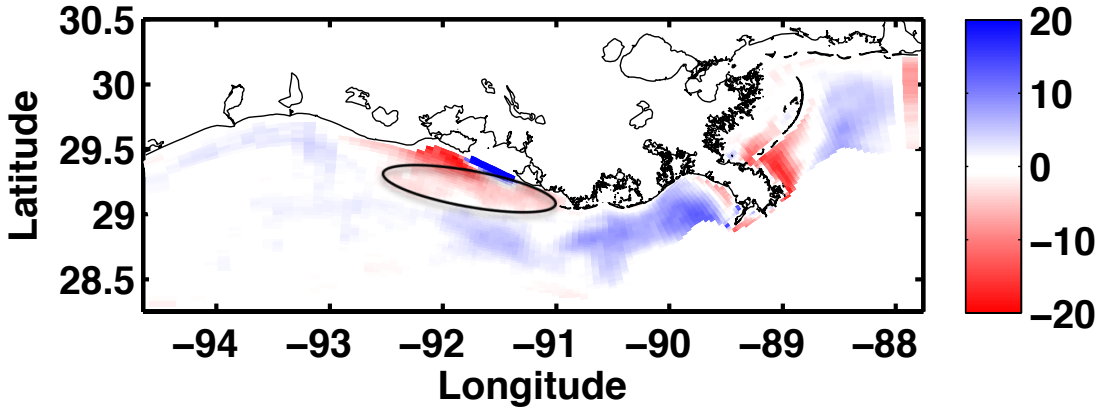
Air–sea flux (mol O_2 m^{-2} y^{-1})



O_2 flux into water

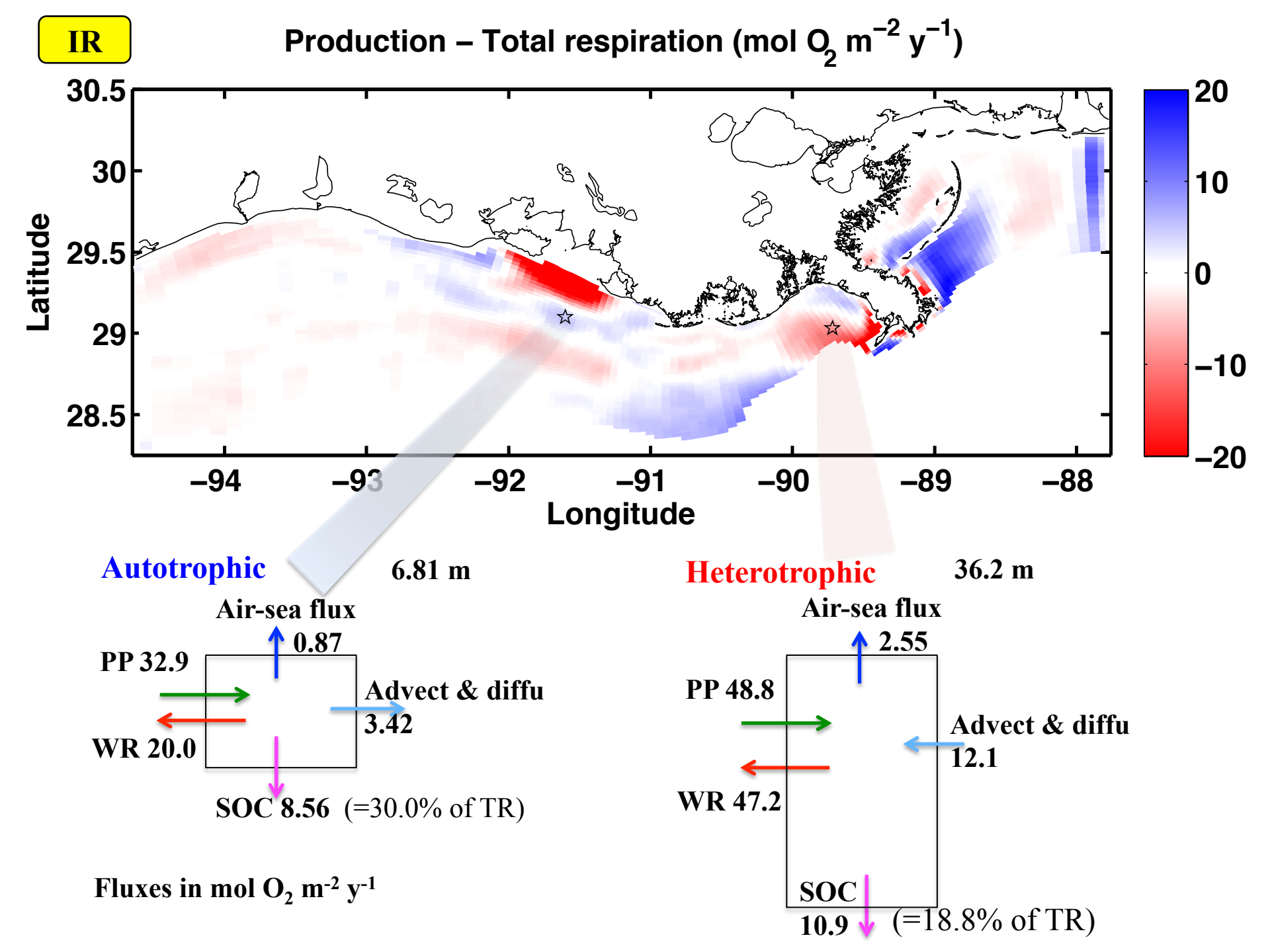
O_2 flux out of water

Advection & diffusion (mol O_2 m^{-2} y^{-1})



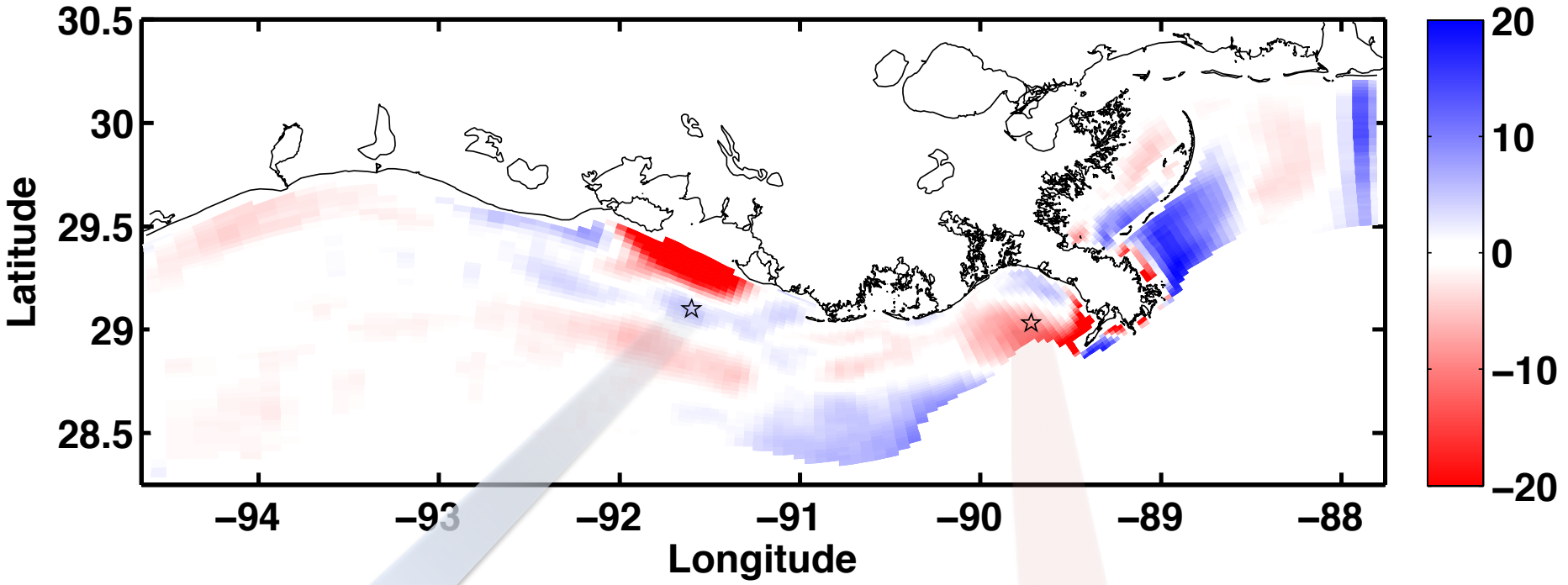
Transport O_2 in

Transport O_2 out

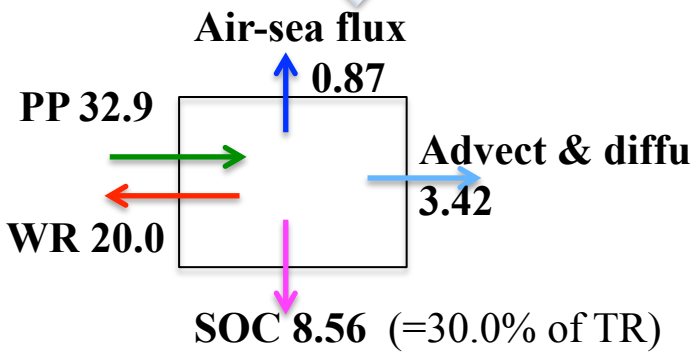

IR
Production – Total respiration (mol O2 m−2 y−1)
30.5
30
29.5
29
28.5
Latitude
−94
−93
−92
−91
−90
−89
−88
Longitude
20
10
0
−10
−20
Autotrophic
6.81 m
Air-sea flux
0.87
PP 32.9
Advect & diffu
3.42
WR 20.0
SOC 8.56 (=30.0% of TR)
Heterotrophic
36.2 m
Air-sea flux
2.55
PP 48.8
Advect & diffu
12.1
WR 47.2
SOC
10.9
(=18.8% of TR)
Fluxes in mol O2 m-2 y-1

IR

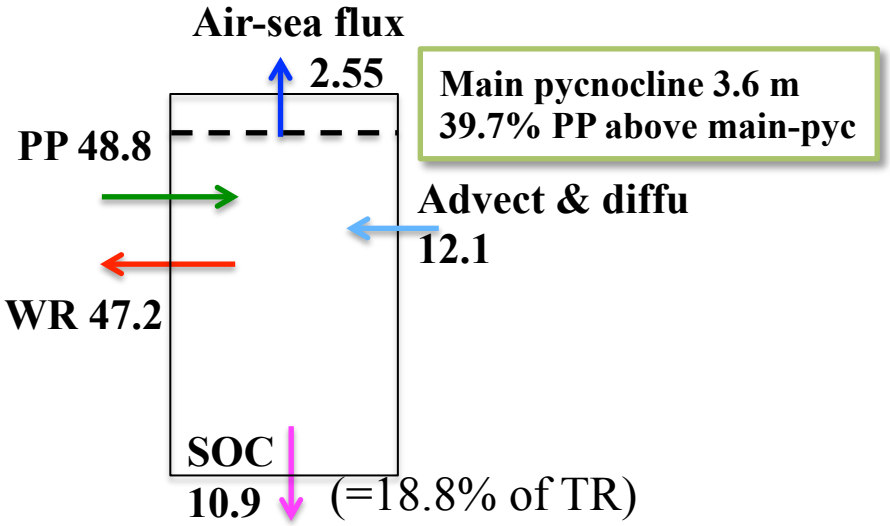
Production – Total respiration (mol O_2 m^{-2} y^{-1})



Autotrophic 6.81 m



Heterotrophic 36.2 m

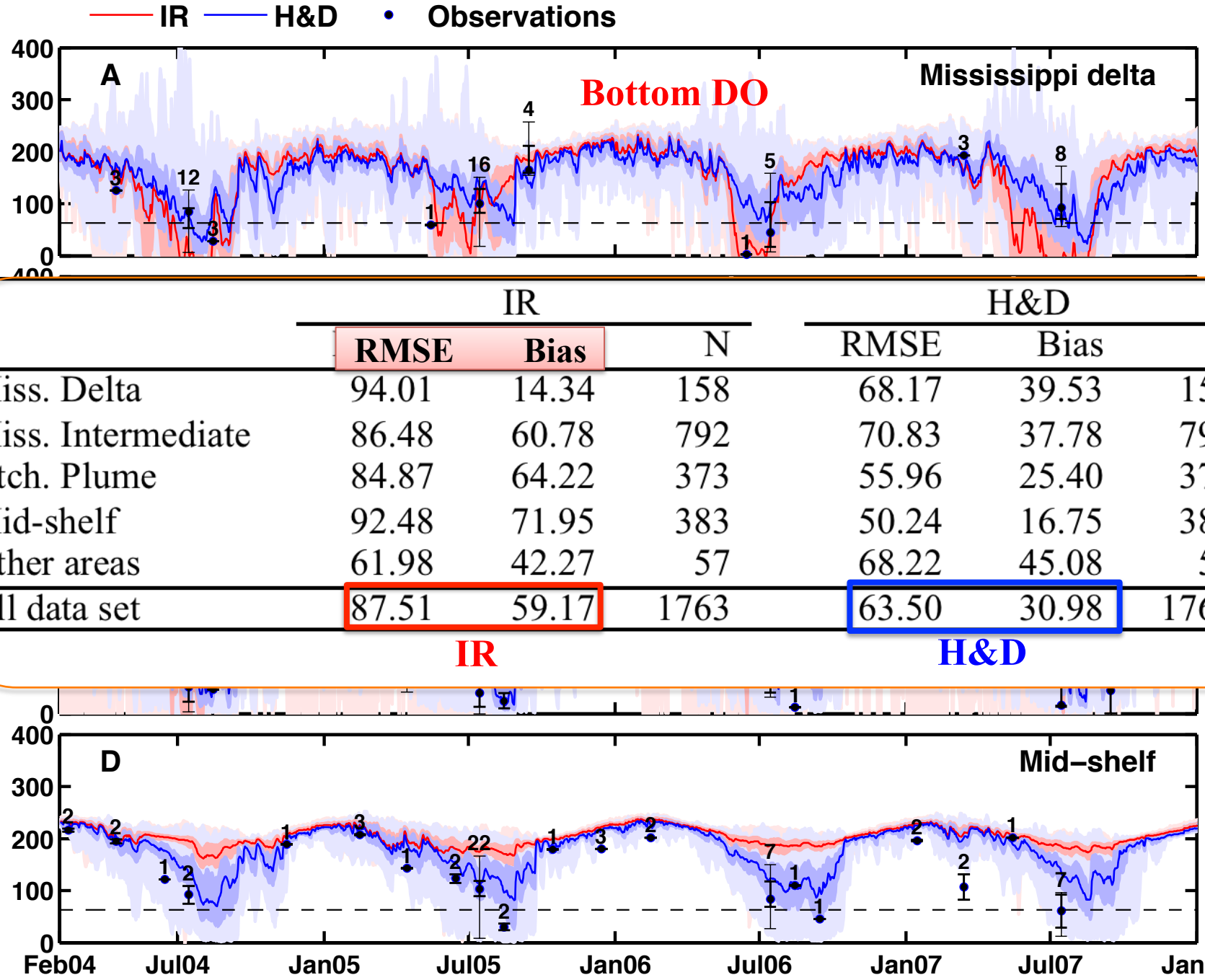


Fluxes in mol O_2 m^{-2} y^{-1}

Conclusions

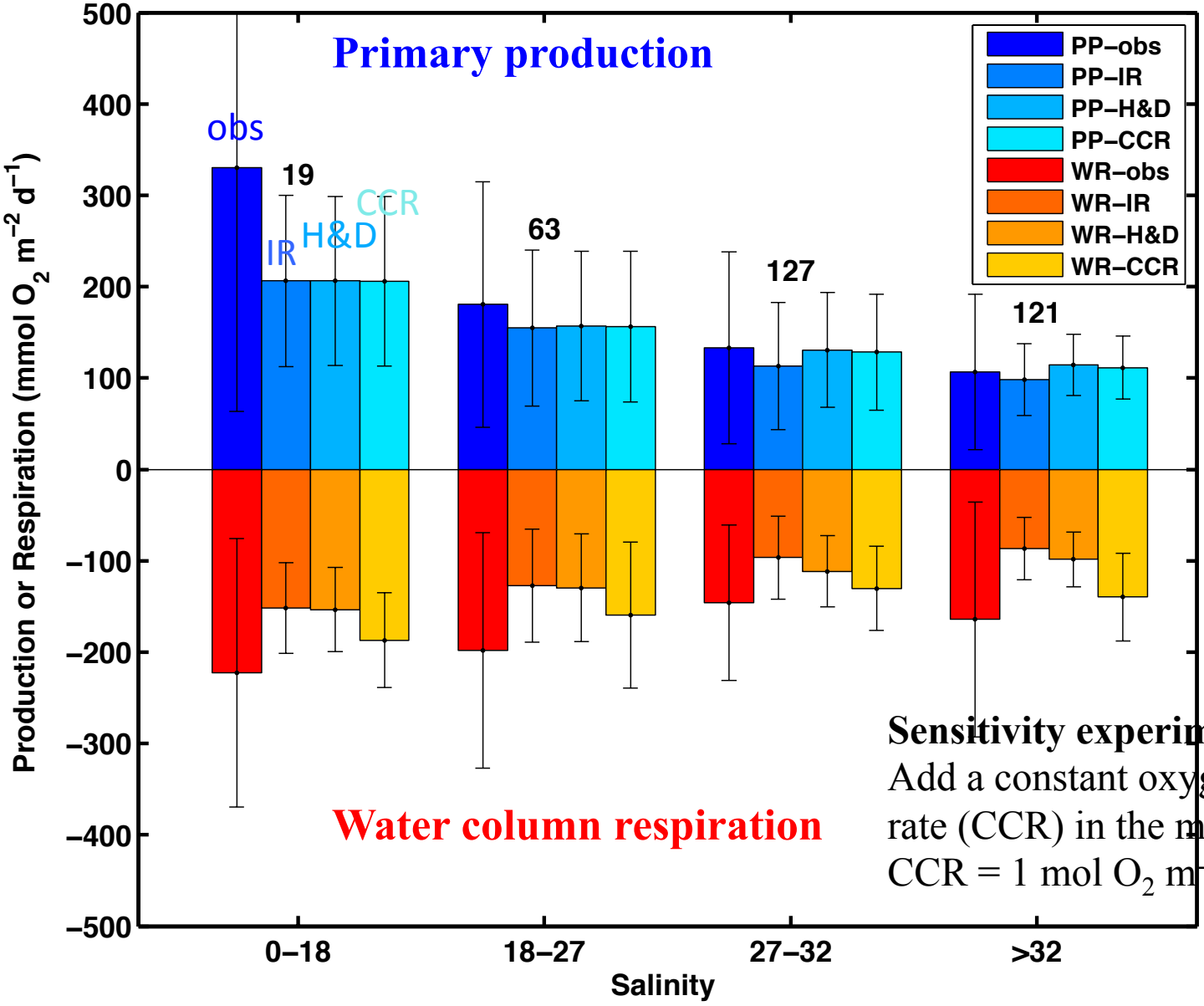
- The model realistically reproduces the observed spatial and temporal patterns of oxygen concentration, primary production and respiration.
- Heterotrophy is most obvious near the river mouth and spreads westward along the shelf, interspersed with regions of autotrophy.
- Oxygen is outgassing in autotrophic regions. In heterotrophic regions, oxygen is taken up by the ocean if stratification is weak, but outgases when stratification is strong.
- Generally, advection transports oxygen from autotrophic to heterotrophic regions.

Thank you !



	IR			H&D		
	RMSE	Bias	N	RMSE	Bias	N
Miss. Delta	94.01	14.34	158	68.17	39.53	158
Miss. Intermediate	86.48	60.78	792	70.83	37.78	792
Atch. Plume	84.87	64.22	373	55.96	25.40	373
Mid-shelf	92.48	71.95	383	50.24	16.75	383
Other areas	61.98	42.27	57	68.22	45.08	57
All data set	87.51	59.17	1763	63.50	30.98	1763

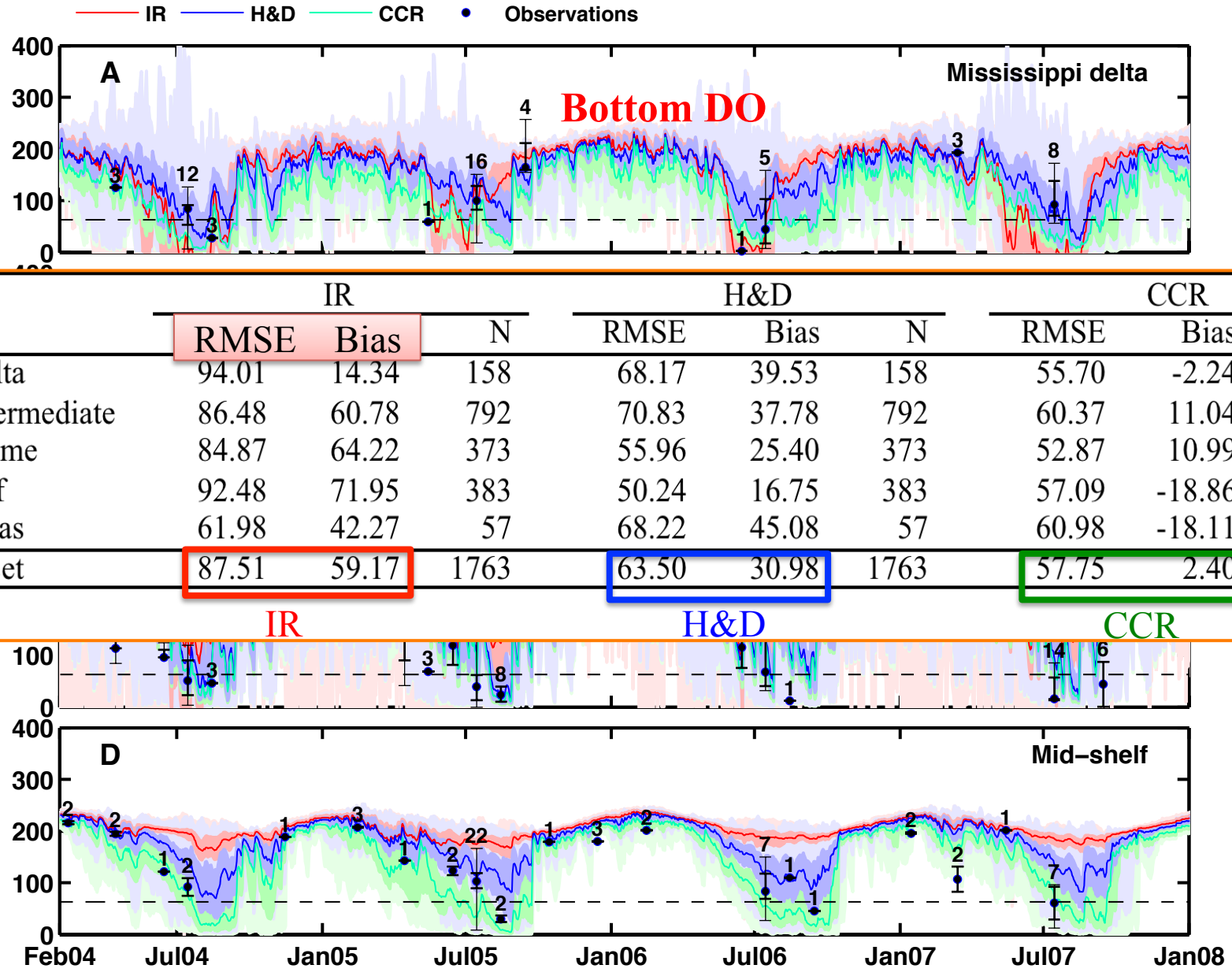
IR H&D



Sensitivity experiment

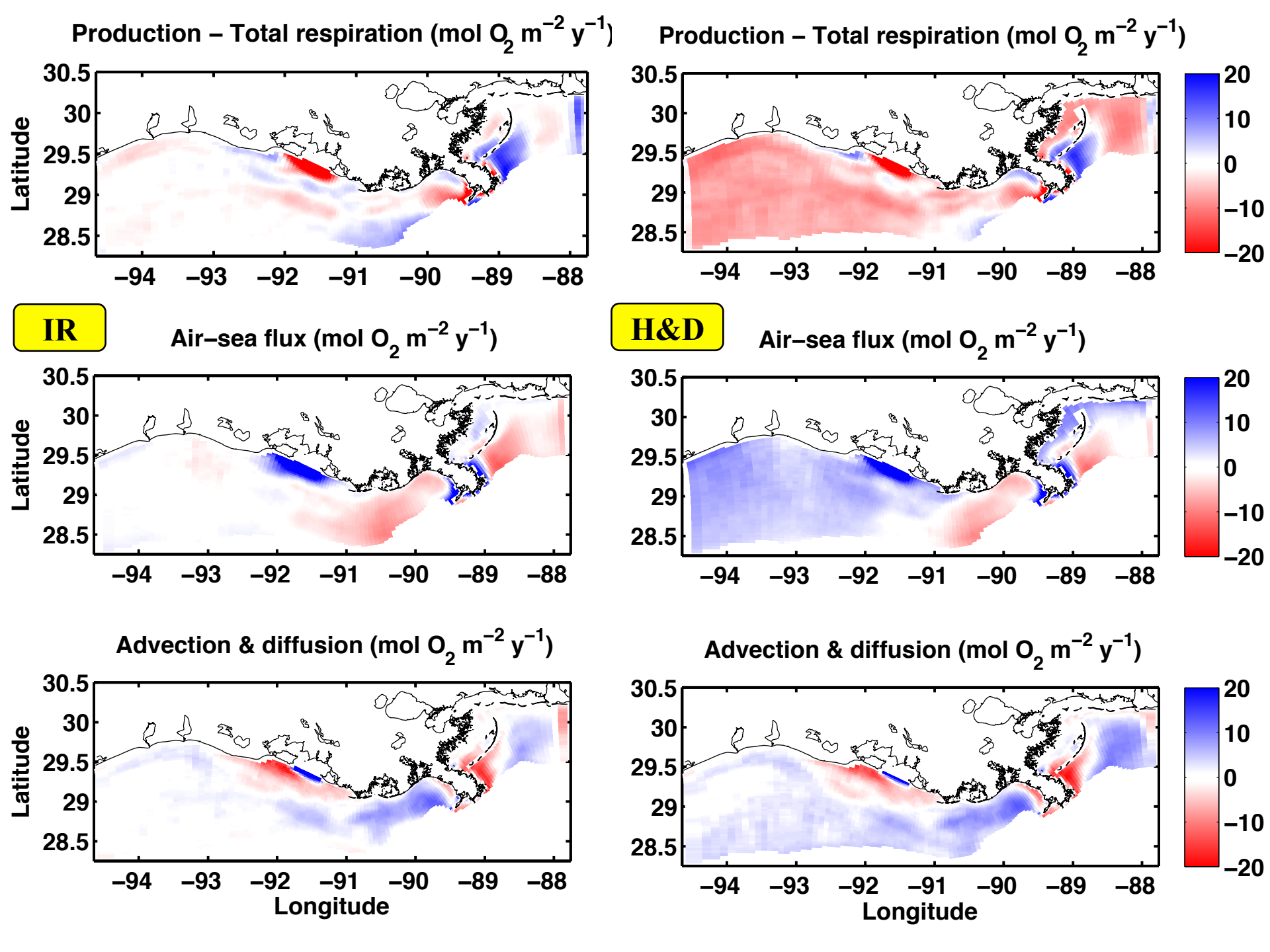
Add a constant oxygen consumption rate (CCR) in the model

CCR = 1 mol O_2 m^{-3} day^{-1}



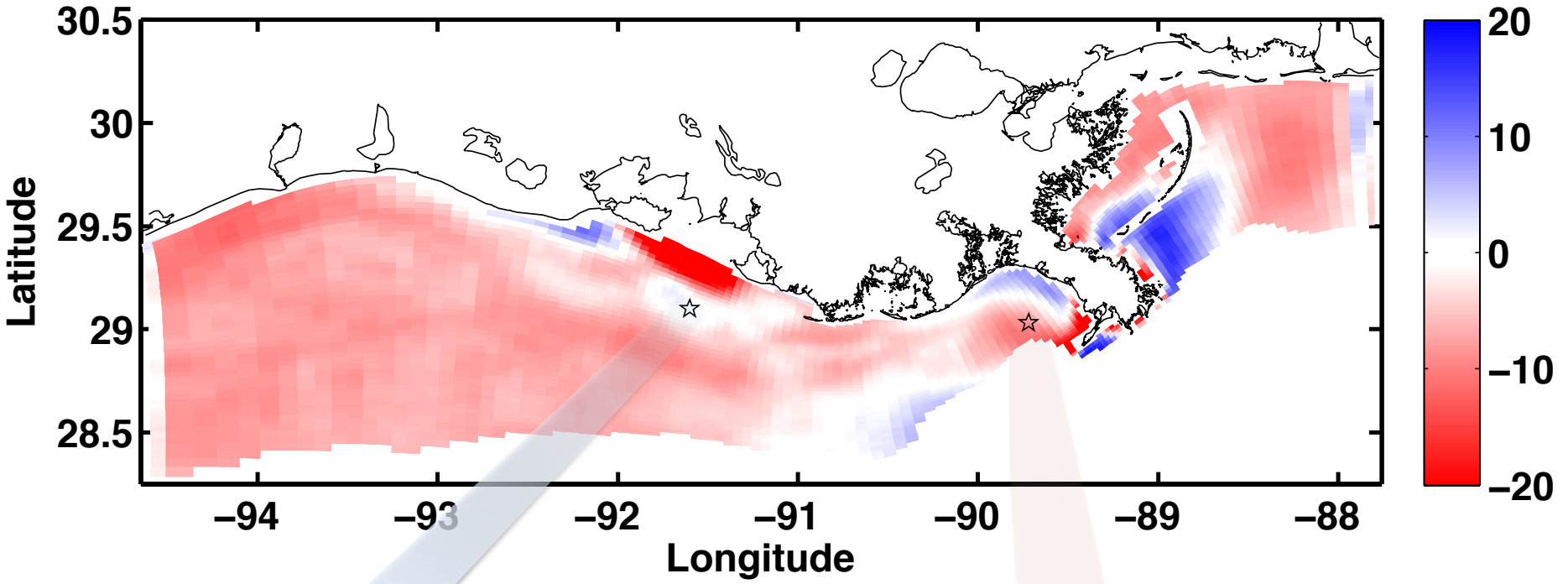
	IR			H&D			CCR		
	RMSE	Bias	N	RMSE	Bias	N	RMSE	Bias	N
Miss. Delta	94.01	14.34	158	68.17	39.53	158	55.70	-2.24	158
Miss. Intermediate	86.48	60.78	792	70.83	37.78	792	60.37	11.04	792
Atch. Plume	84.87	64.22	373	55.96	25.40	373	52.87	10.99	373
Mid-shelf	92.48	71.95	383	50.24	16.75	383	57.09	-18.86	383
Other areas	61.98	42.27	57	68.22	45.08	57	60.98	-18.11	57
All data set	87.51	59.17	1763	63.50	30.98	1763	57.75	2.40	1763

IR H&D CCR

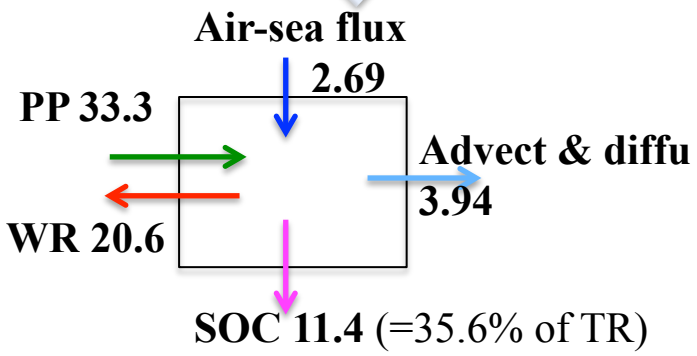

Production – Total respiration (mol O2 m−2 y−1)
Production – Total respiration (mol O2 m−2 y−1)
IR
Air–sea flux (mol O2 m−2 y−1)
H&D
Air–sea flux (mol O2 m−2 y−1)
Advection & diffusion (mol O2 m−2 y−1)
Advection & diffusion (mol O2 m−2 y−1)
Latitude
Longitude
30.5
30
29.5
29
28.5
−94
−93
−92
−91
−90
−89
−88
20
10
0
−10
−20

H&D

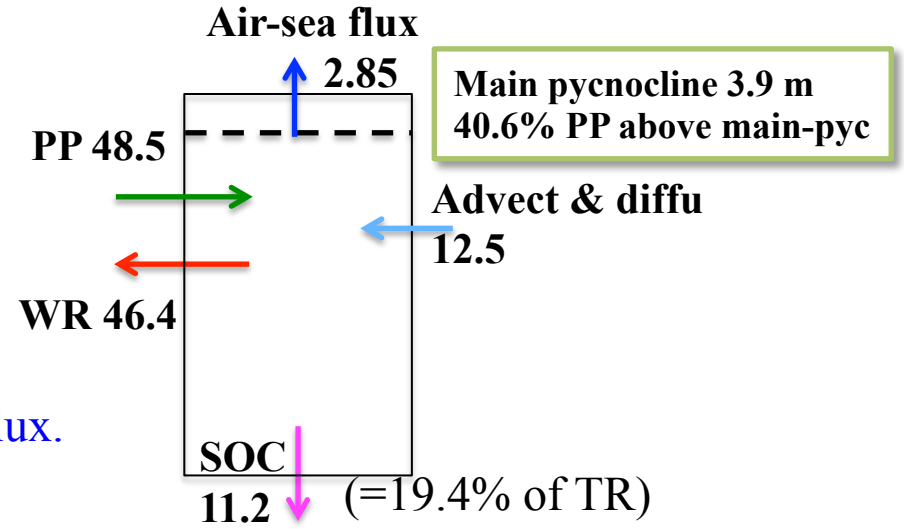
Production – Total respiration (mol O_2 m^{-2} y^{-1})



Autotrophic 6.81 m



Heterotrophic 36.2 m



IR and H&D mainly differs in SOC and air-sea flux.