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Challenges associated with modeling low-oxygen waters in Chesapeake Bay: a multiple model comparison

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COMT Estuarine Hypoxia Team

Challenges associated with simulating low-oxygen waters in Chesapeake Bay: a multiple model comparison

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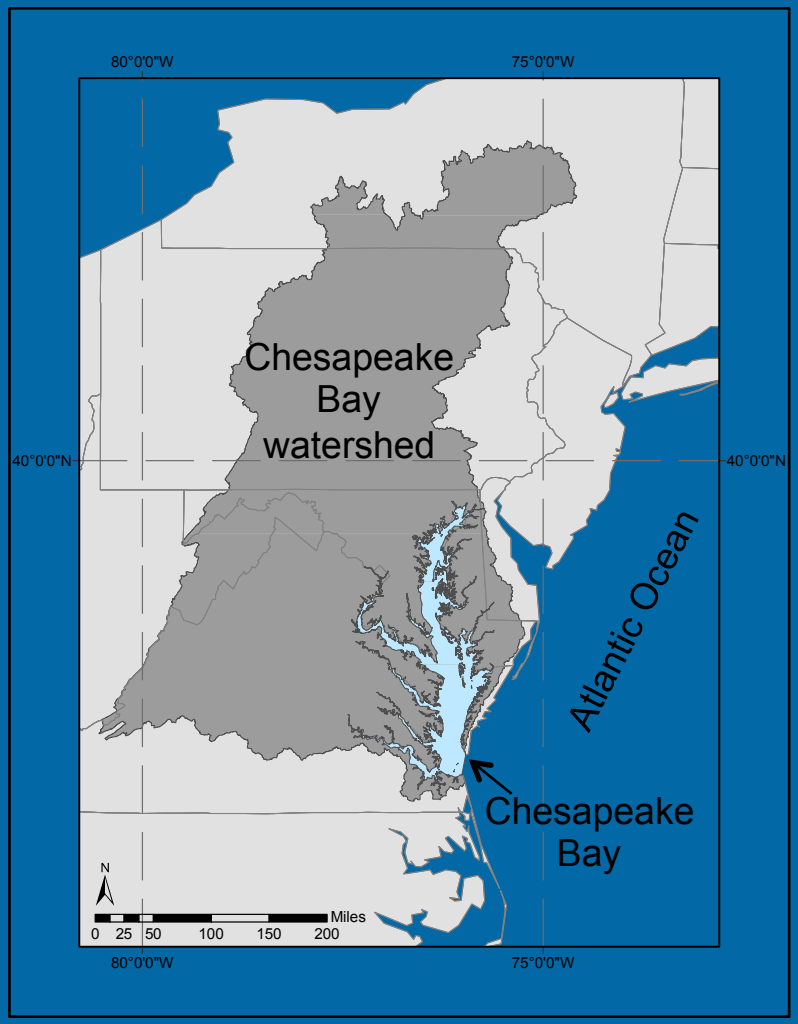
VIRGINIA INSTITUTE OF MARINE SCIENCE

1940-2015 75 YEARS

Modelers involved in study:

P. Wang, L. Linker	CH3D-ICM
Y. Feng	ROMS-ECB
R. Hood, H. Wang	ROMS-BGC
J. Testa	ROMS-RCA
M. Xia	FVCOM-ICM
M. Scully	ROMS
L. Lanerolle	CBOFS
J. Shen	EFDC

Chesapeake Bay



- Historical Water Quality Issues
- Regulatory Actions
  - Dissolved Oxygen
- Modeling Efforts
  - Government
  - Academia

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Motivating Question

How can we improve model simulations of low-oxygen conditions in the Chesapeake Bay?

Models Evaluated in Study

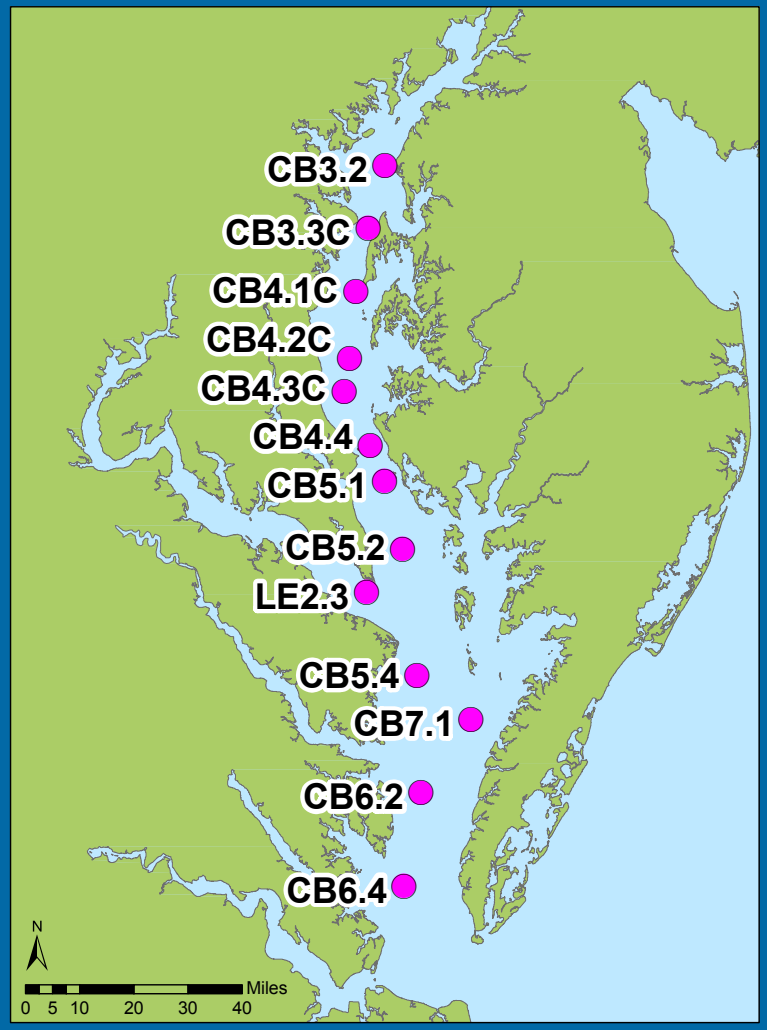
8 Different Models

- **5 full BGC models of varying complexity and resolution**
- **3 constant respiration models of varying resolution**

- **2 models used by government agencies**
- **6 models used by academia**
- **Not all focused on water quality**

8 Different Models + Model Ensemble Mean = 9 Total Models

Methods: Observations



- 13 Observation Stations
  - 2004 – 2005
  - 1-2 times a month
  - *Seasonal Variability

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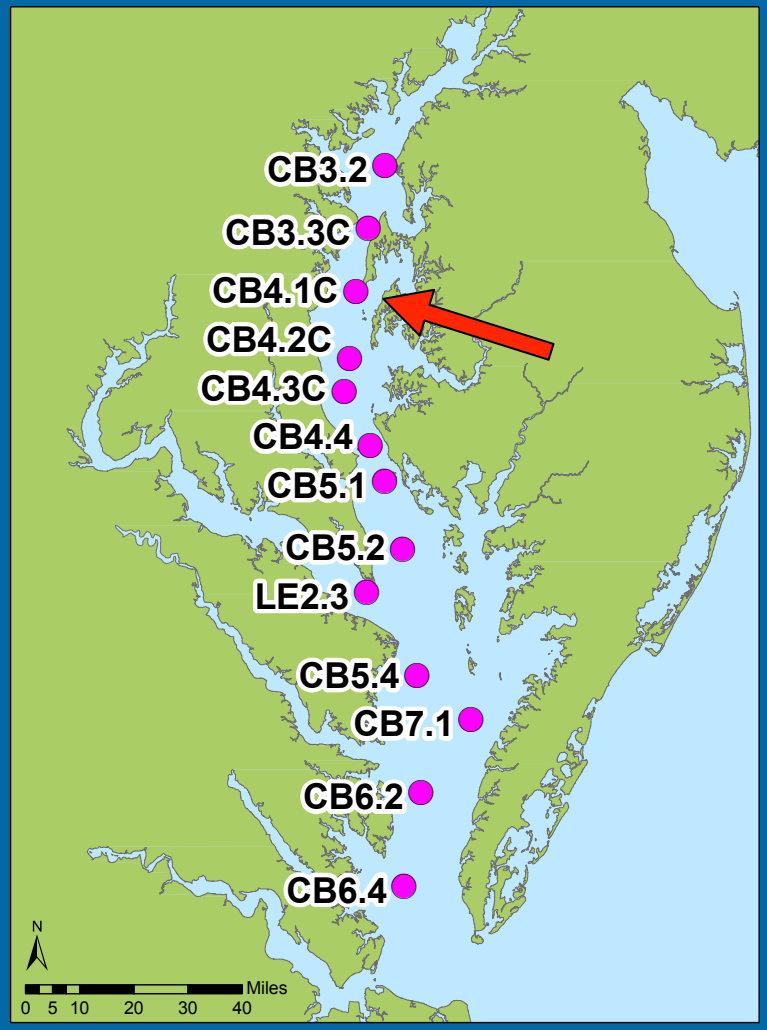
1940-2015 75 Years

Methods: Observations



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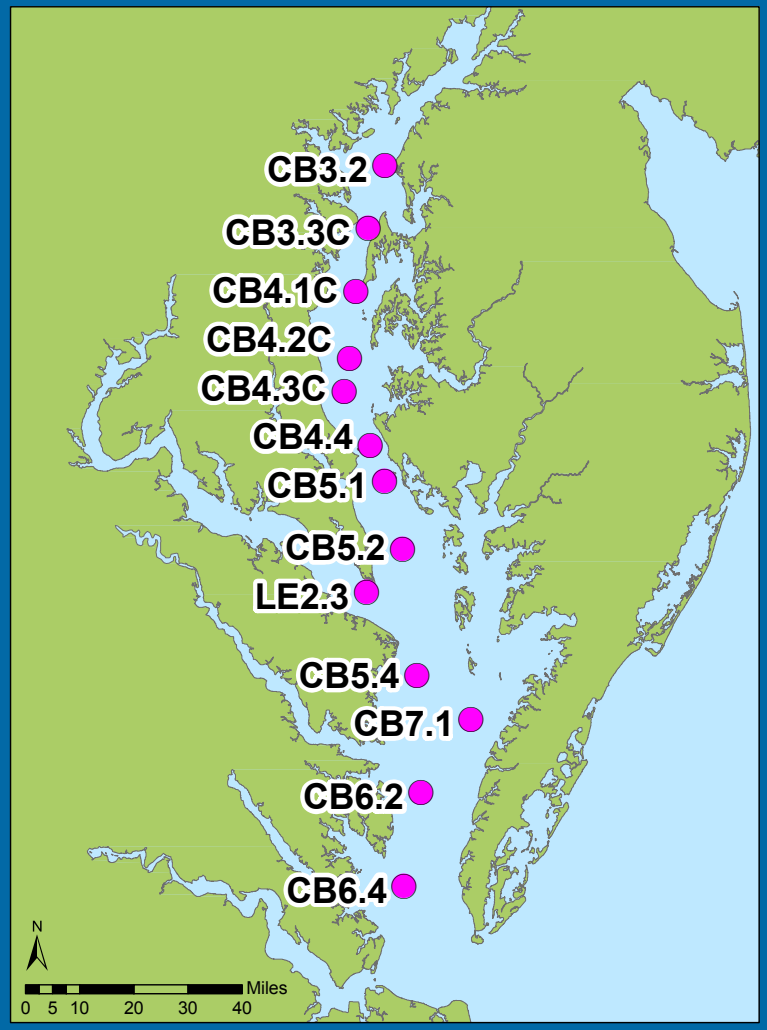

- 13 Observation Stations
  - 2004 – 2005
  - 1-2 times a month
  - *Seasonal Variability
- Variables
  - Temperature
  - Salinity
  - Dissolved Oxygen (DO)
  - Chlorophyll
  - Nitrate
  - Stratification
    - Oxycline
    - MLDo

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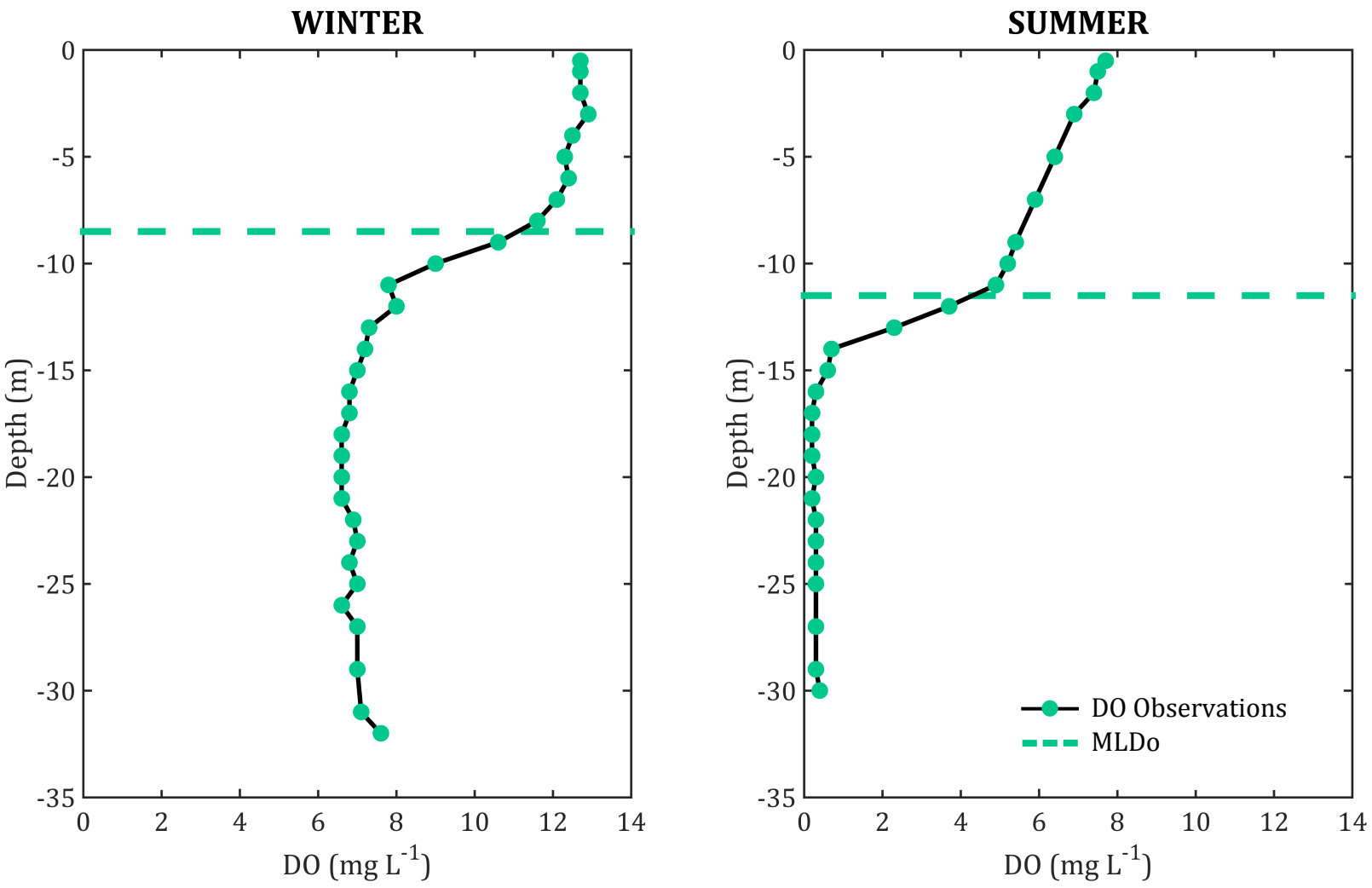
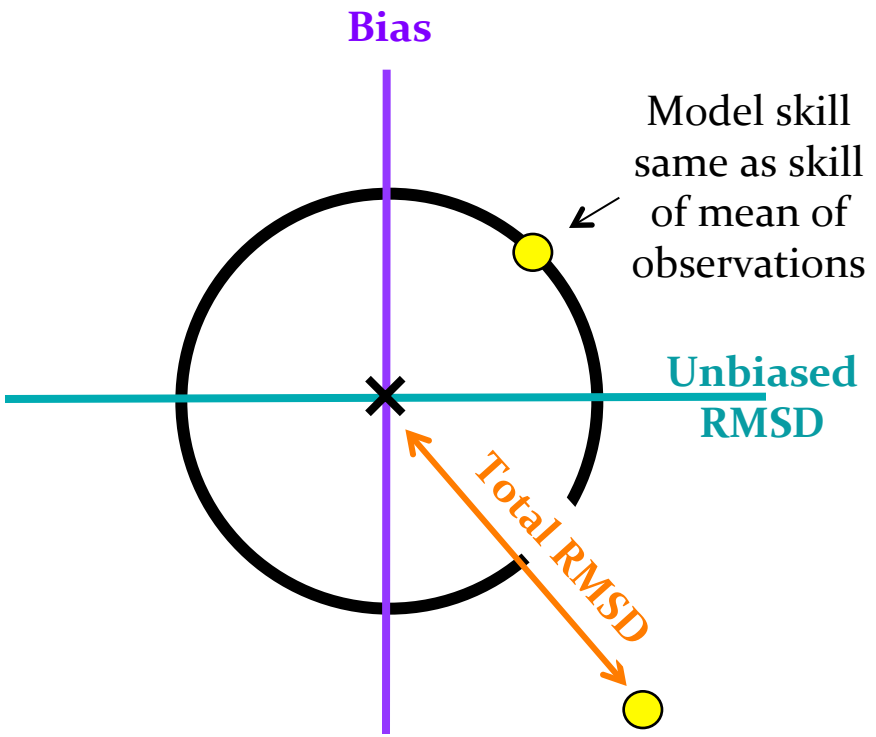
Methods: Stratification

Station CB4.1C

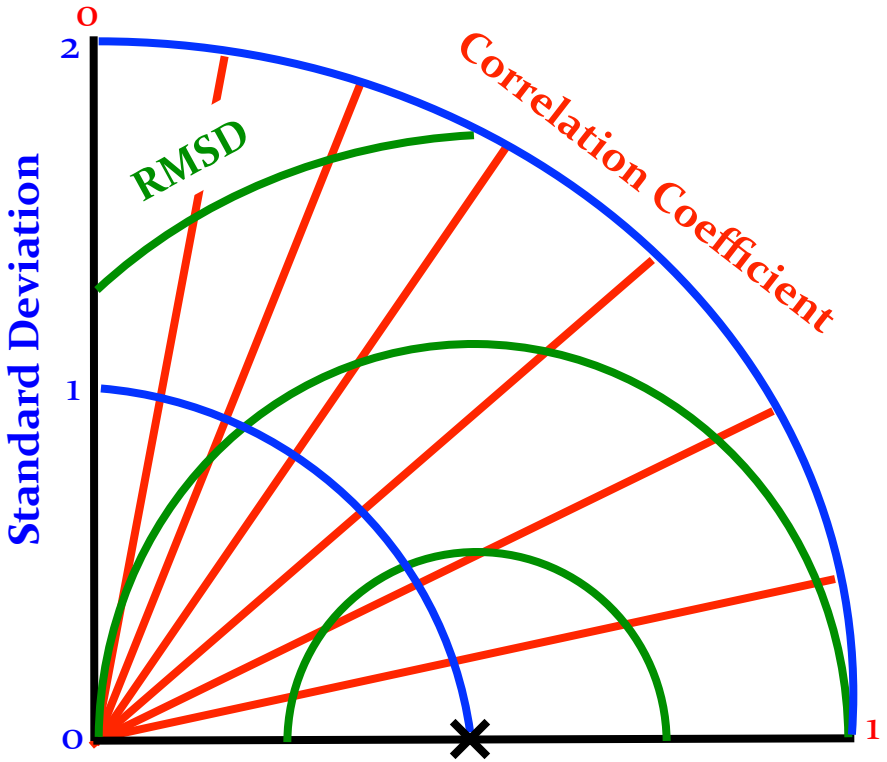


Methods: Skill Assessment

Target Diagram



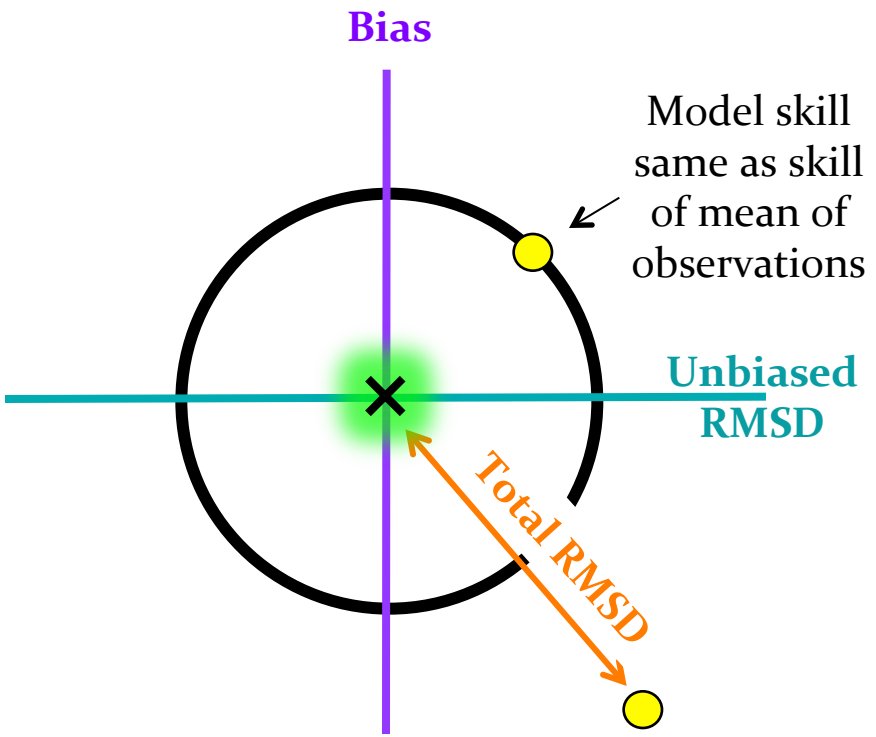
Taylor Diagram



RMSD = Root mean square difference

Methods: Skill Assessment

Target Diagram



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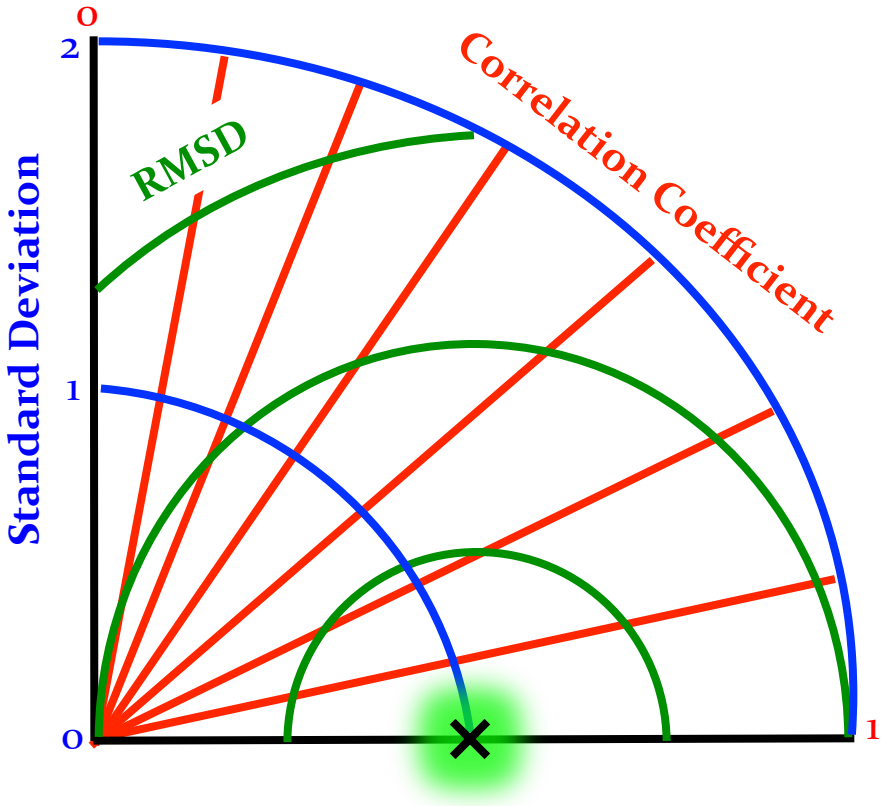

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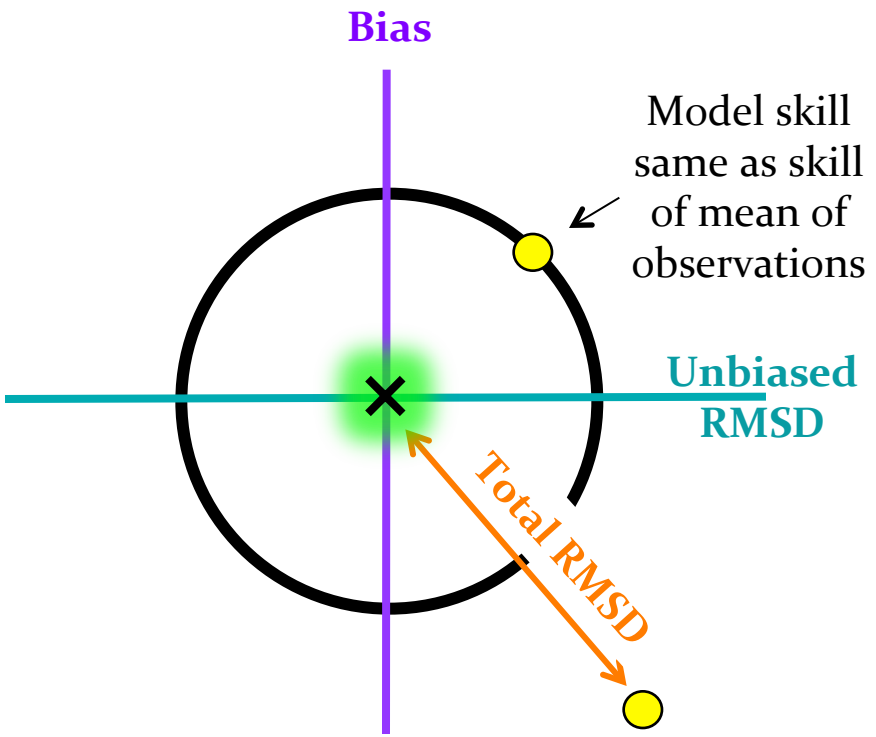

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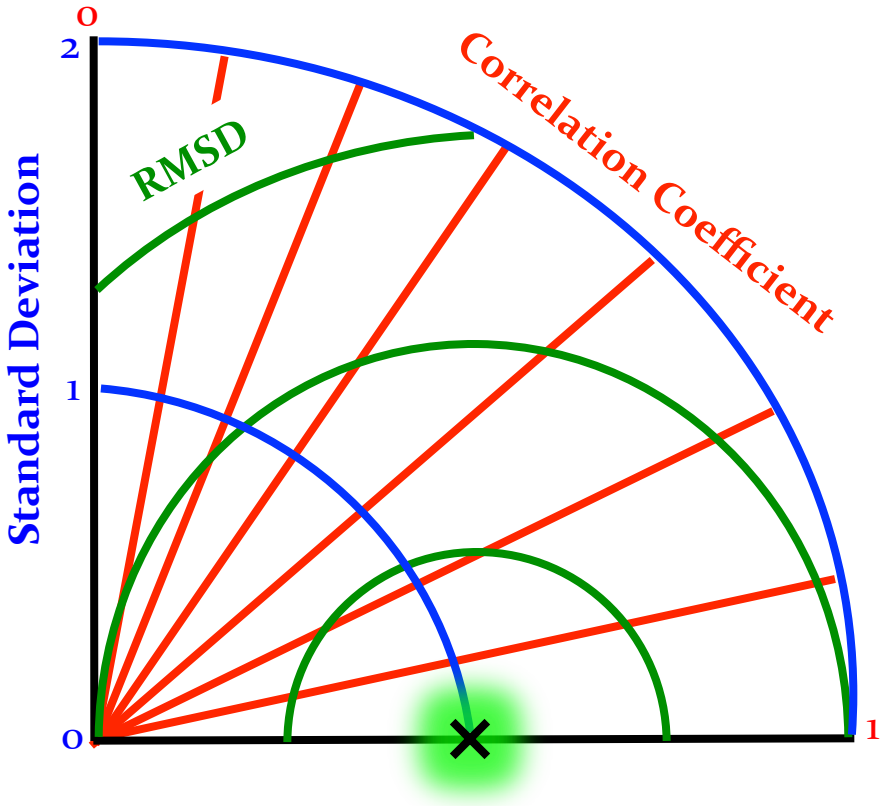
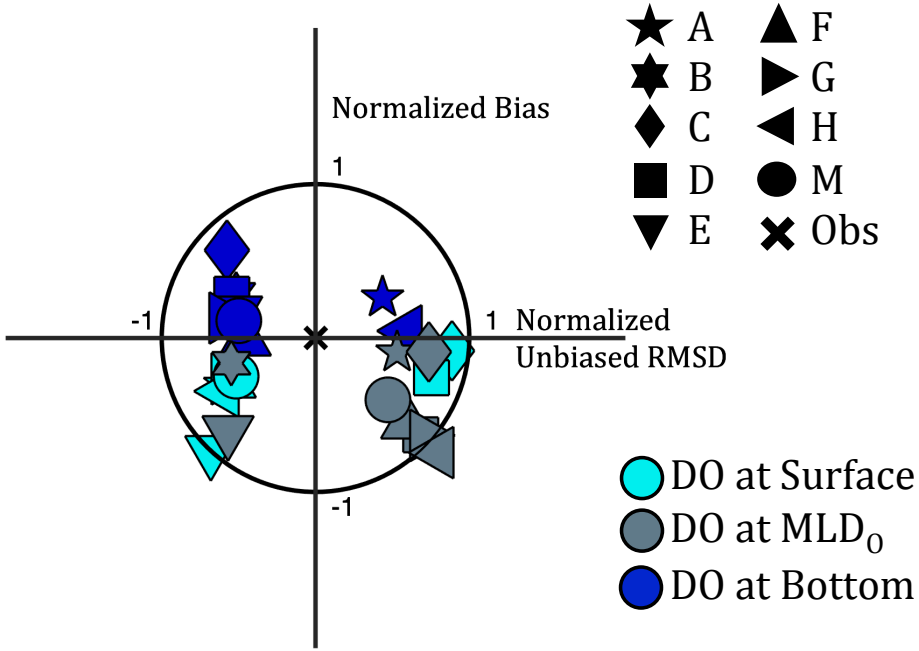
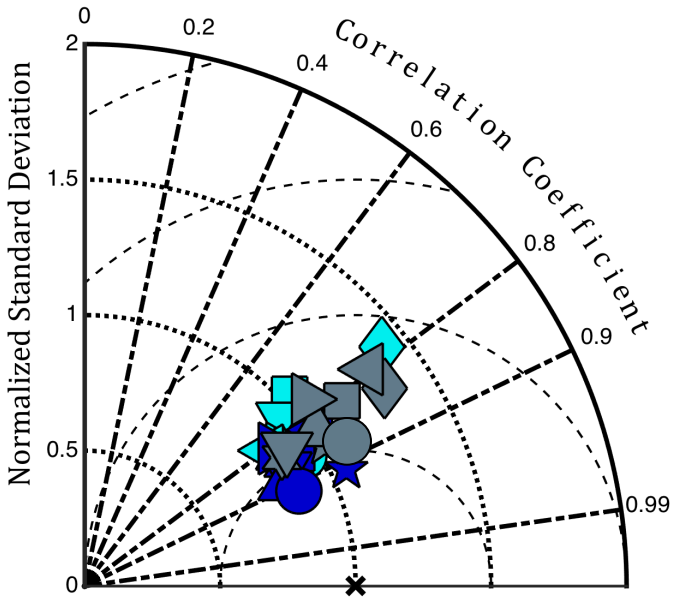


RMSD = Root mean square difference

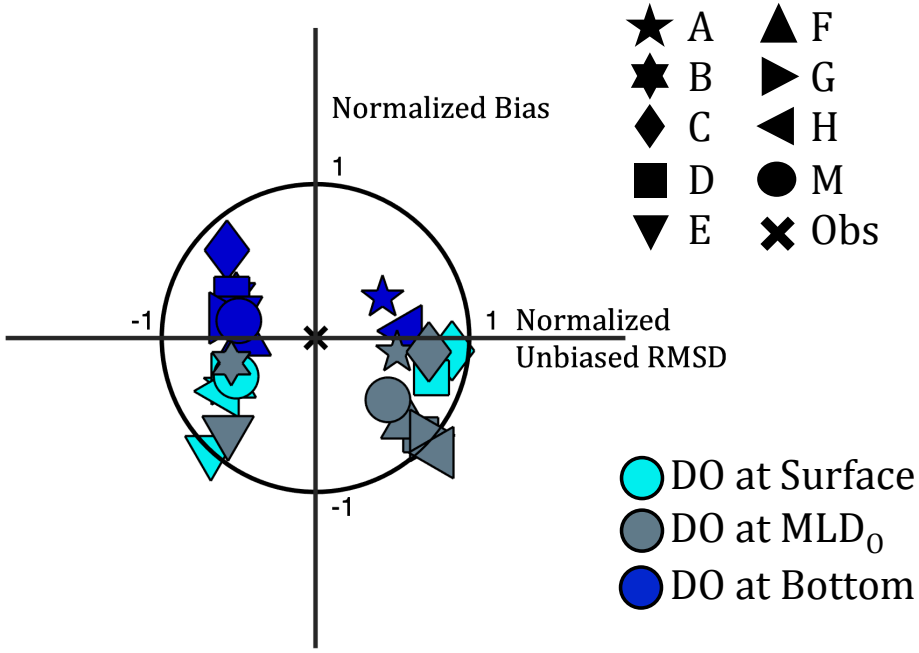
*Normalized

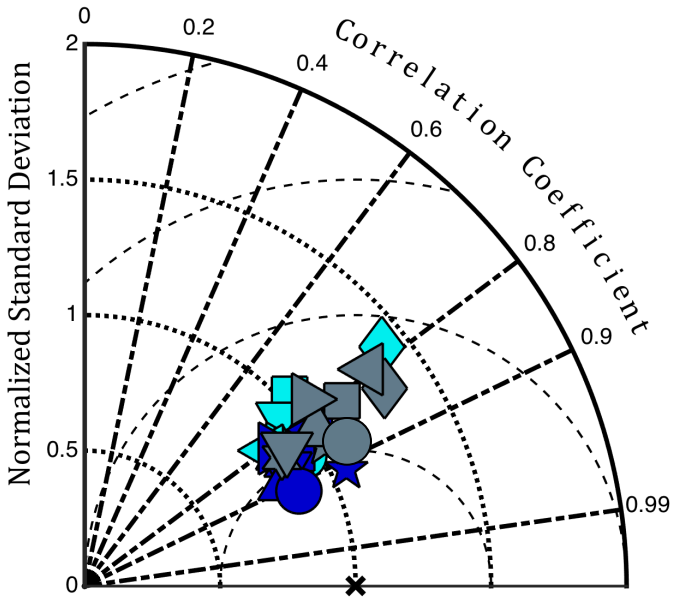
Dissolved Oxygen





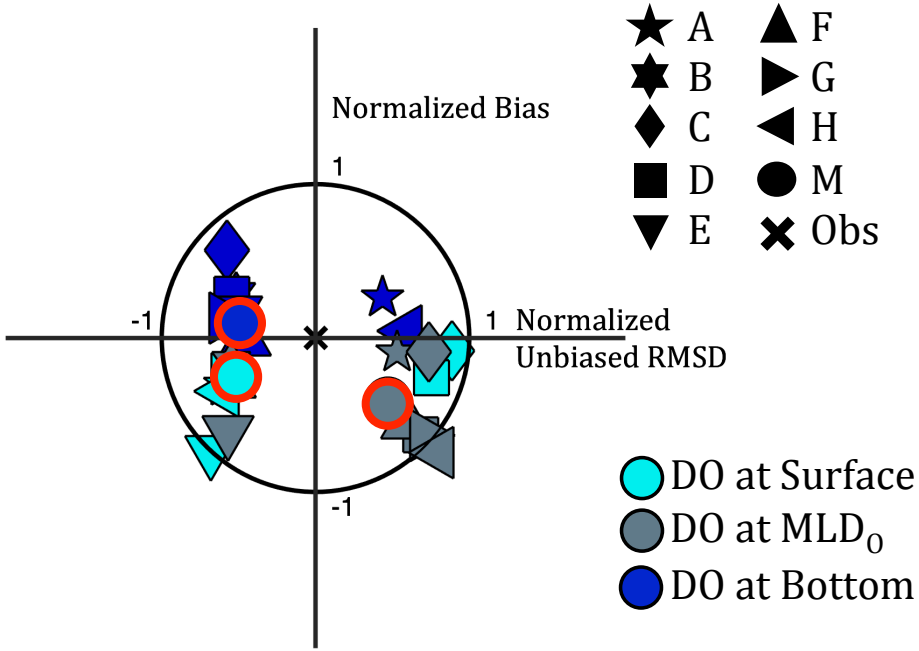
Dissolved Oxygen

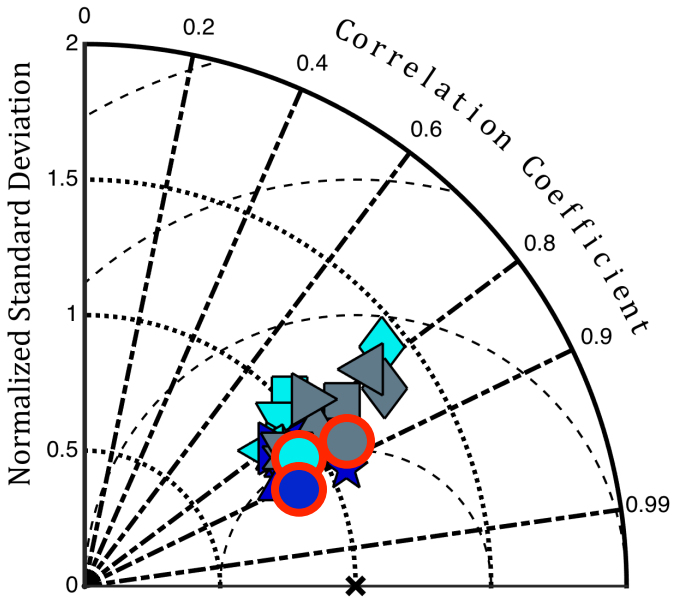




All models, regardless of biogeochemical complexity, do well.

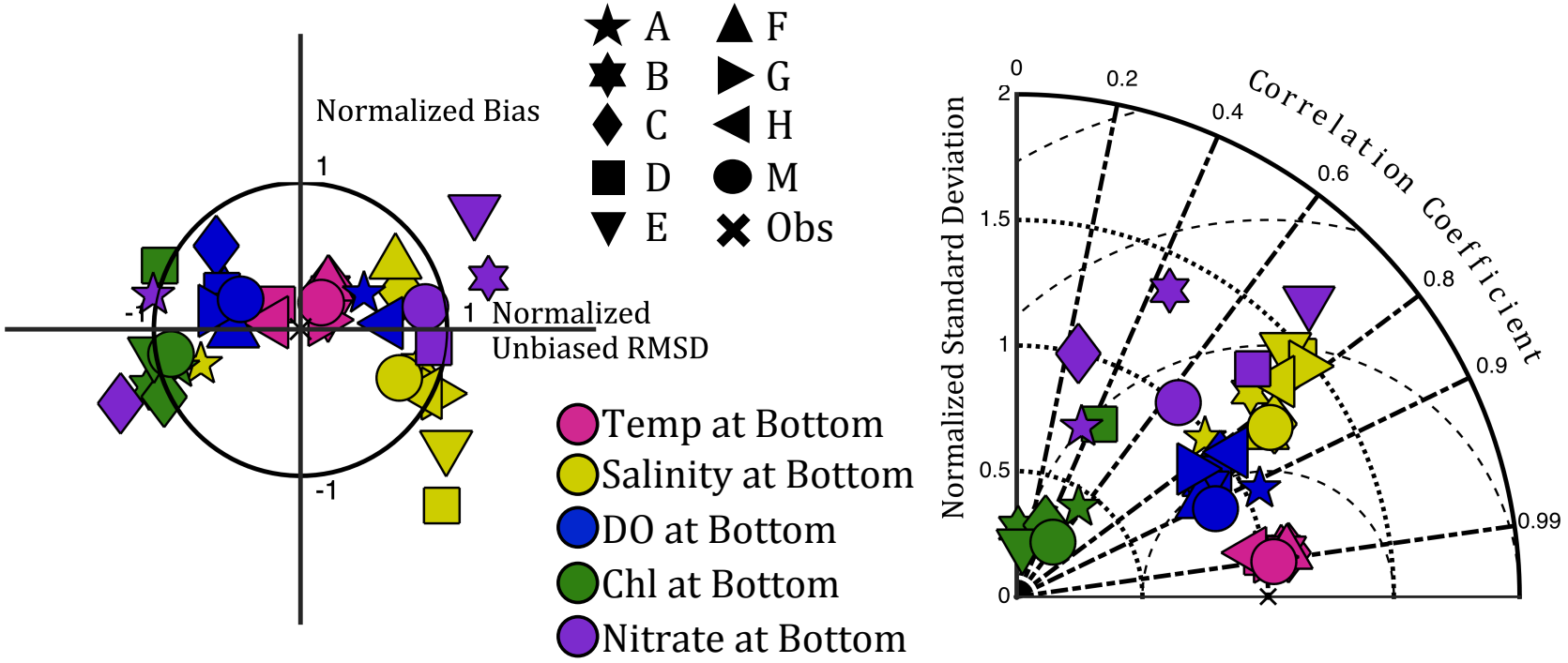
Dissolved Oxygen



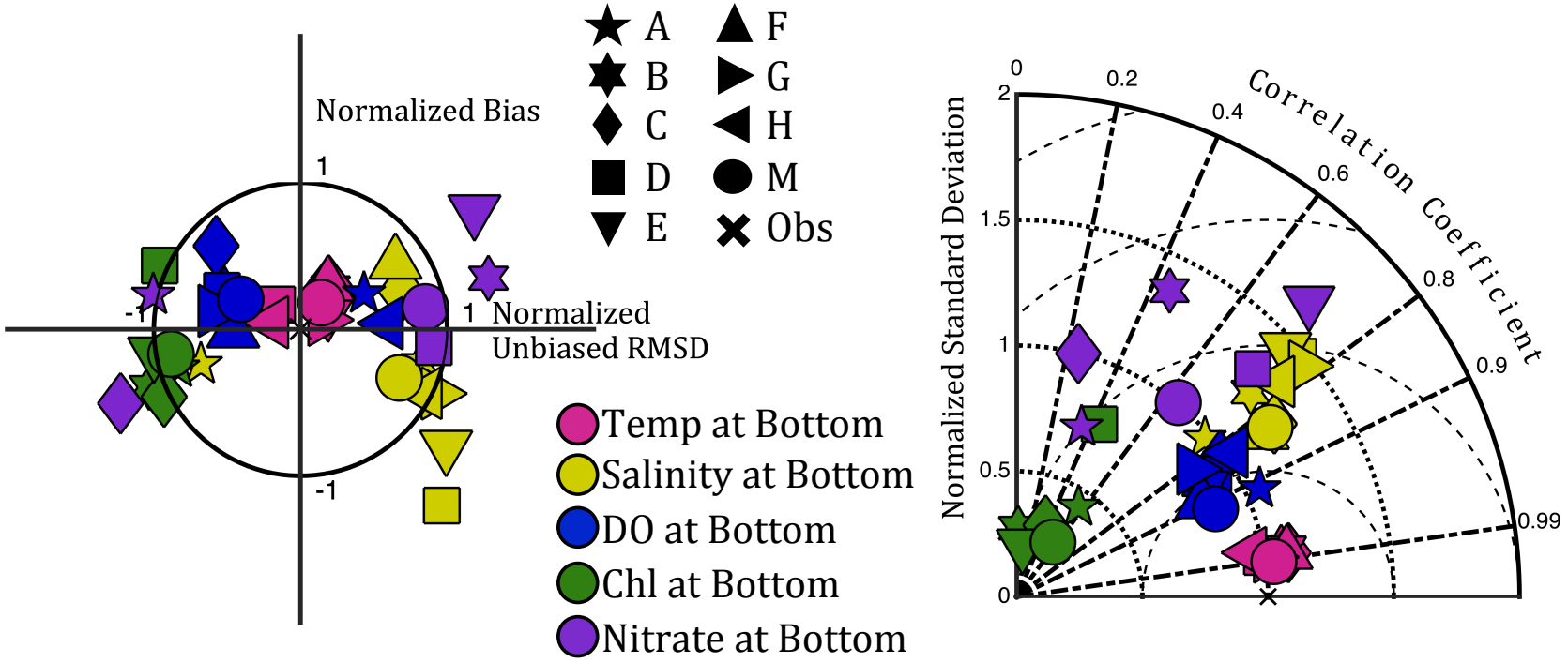


The model mean performs better than any single model.

Variables Driving DO Variability



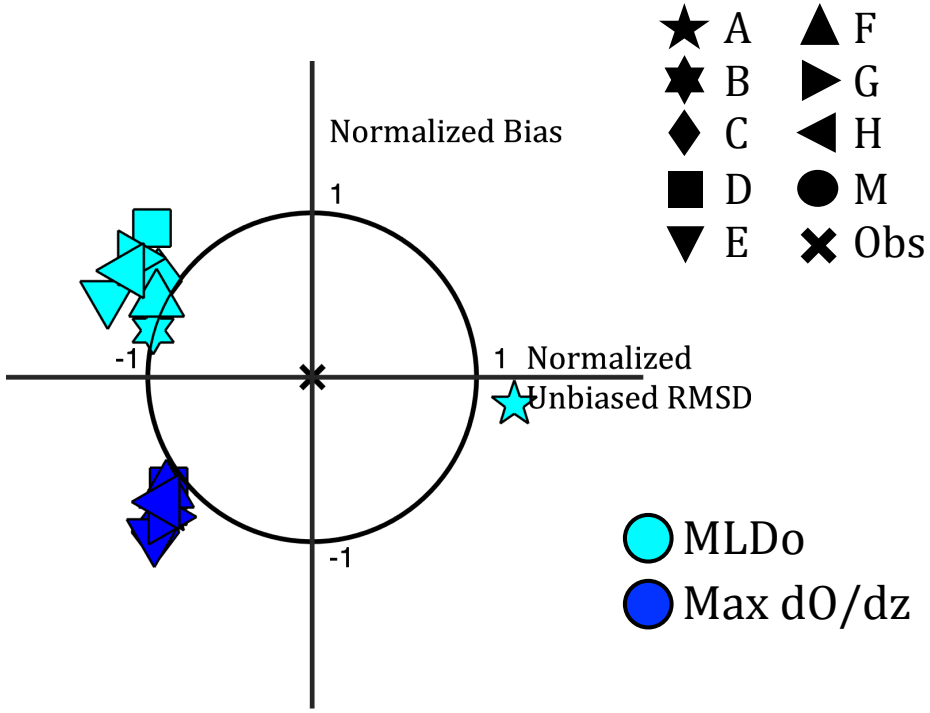
Variables Driving DO Variability

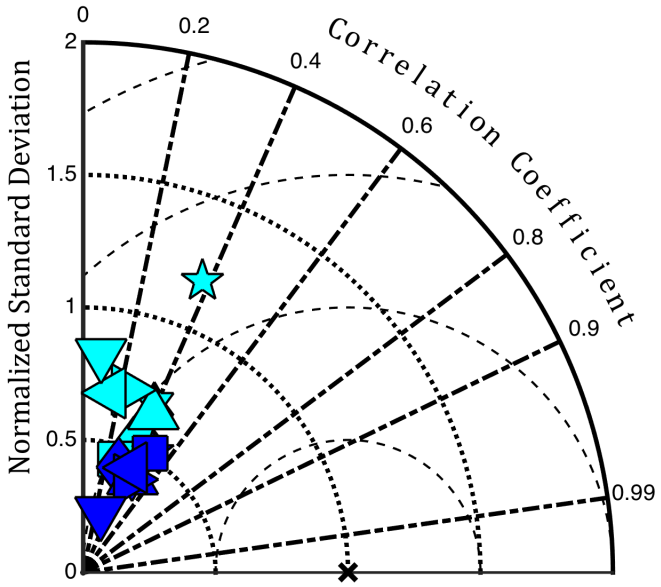


Models simulate temperature the best.

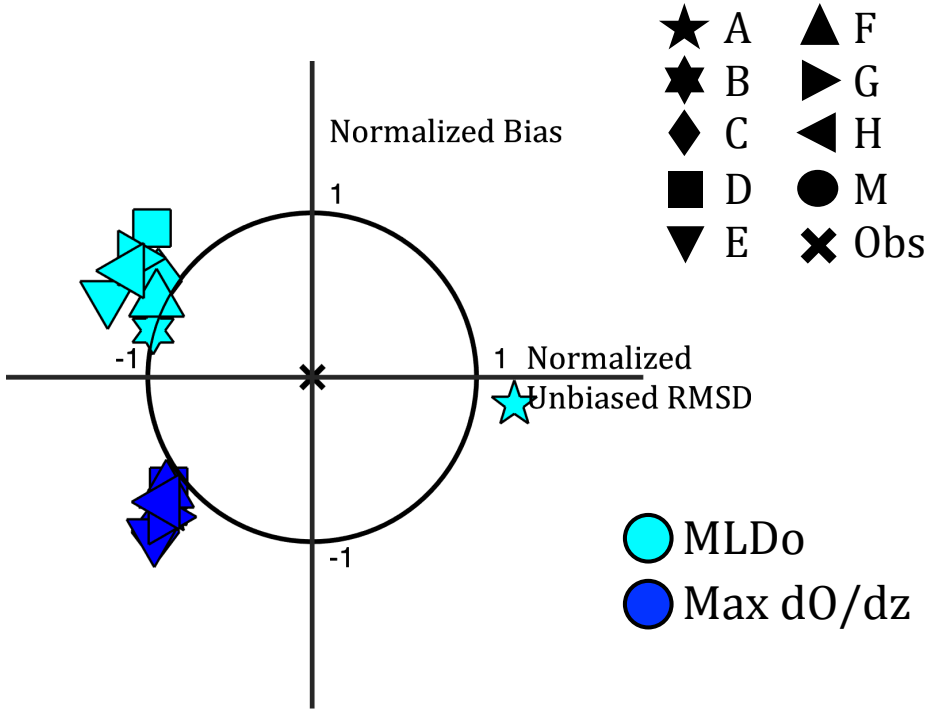
Models simulate bottom DO better than salinity, chl, and NO_3.

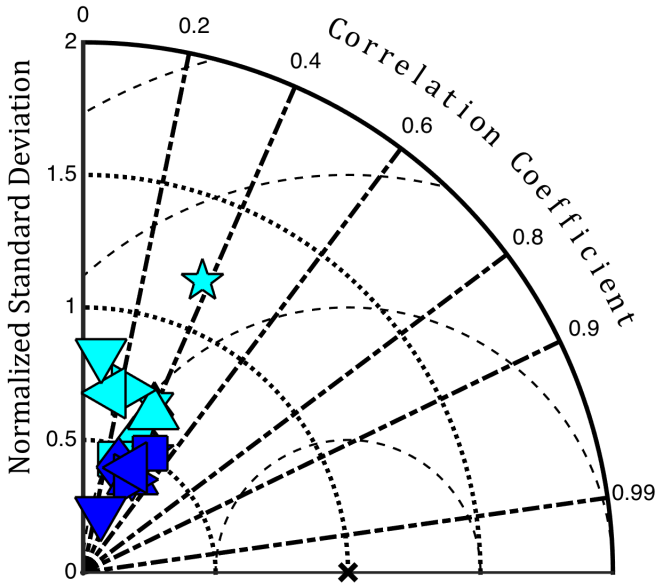
Oxygen Stratification





Oxygen Stratification

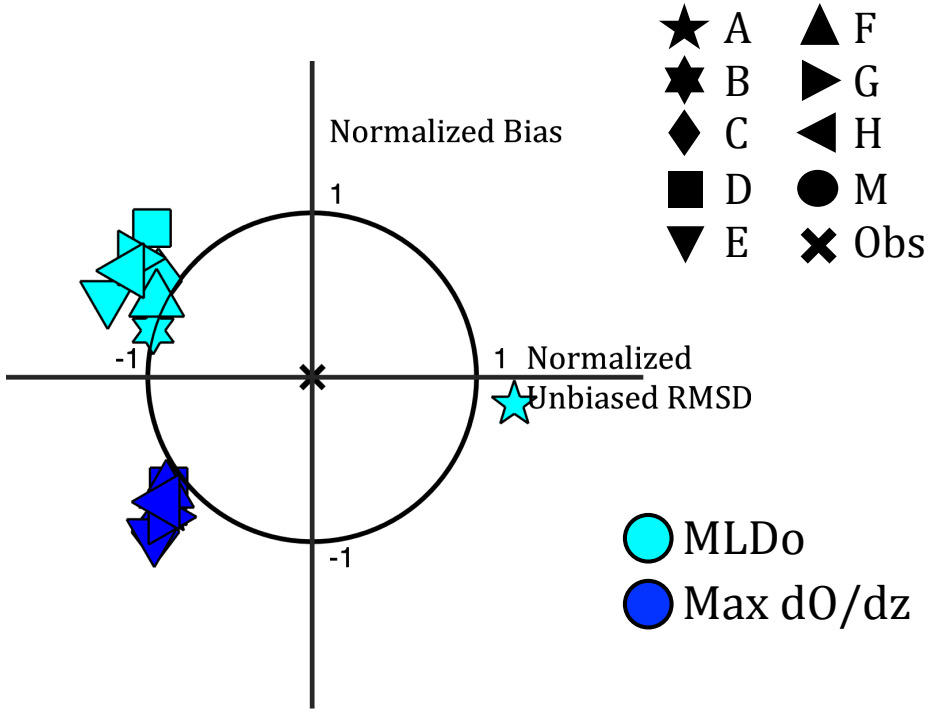


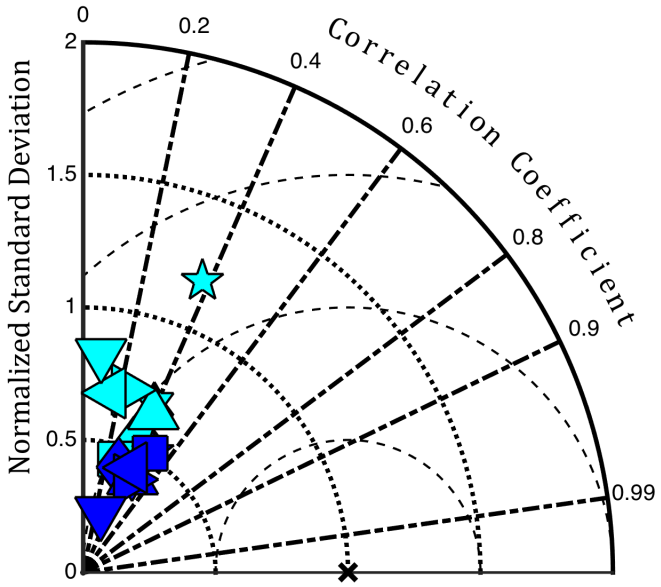


Models underestimate degree and variability of vertical gradient.
Models place MLDo too high in water column and miss variability.

Oxygen Stratification

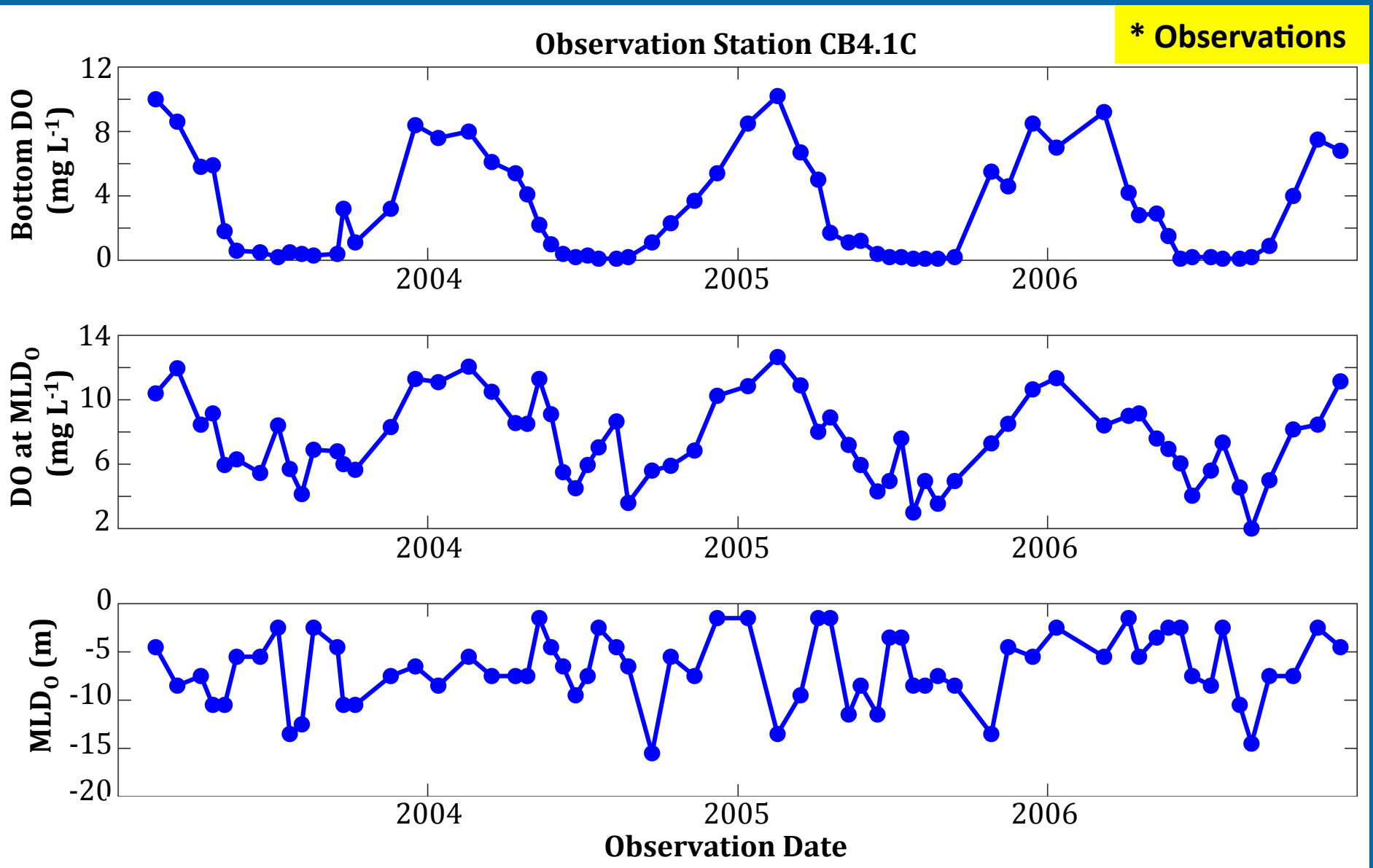
But we already established that the models resolve DO well throughout the water column.

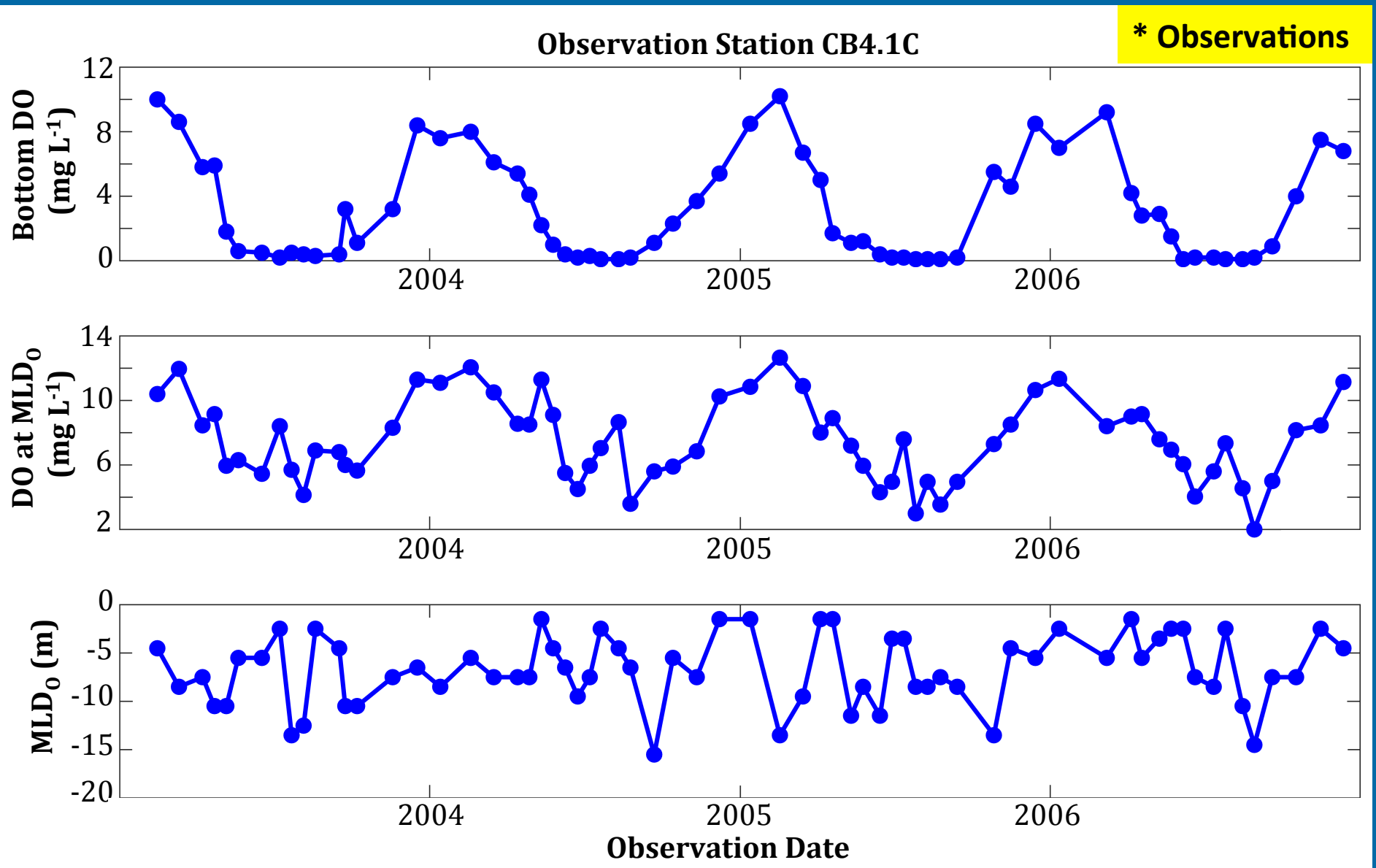




Models underestimate degree and variability of vertical gradient.
Models place MLDo too high in water column and miss variability.

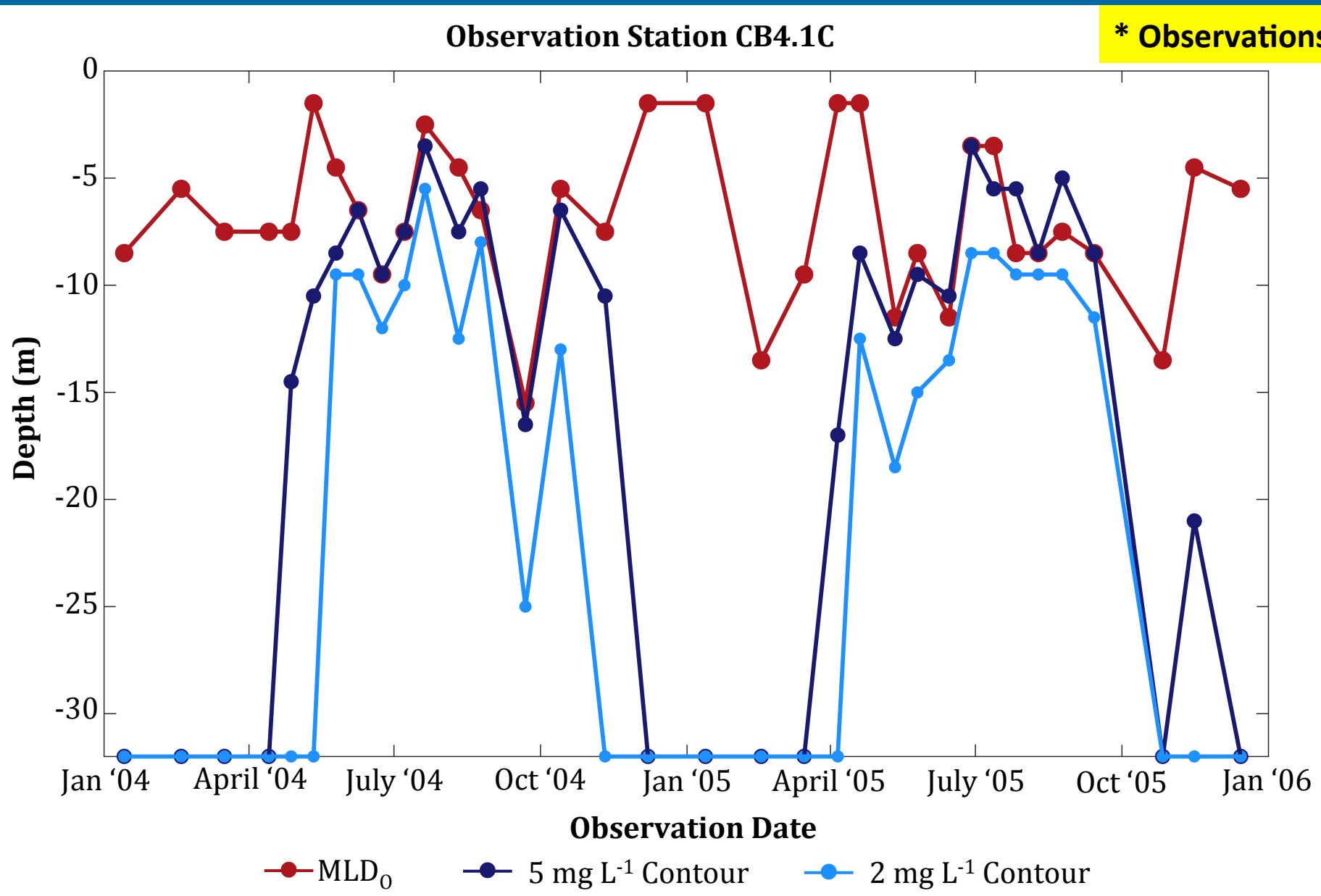
How can models simulate DO well throughout the water column while missing the maximum value of the oxycline and the MLDo?

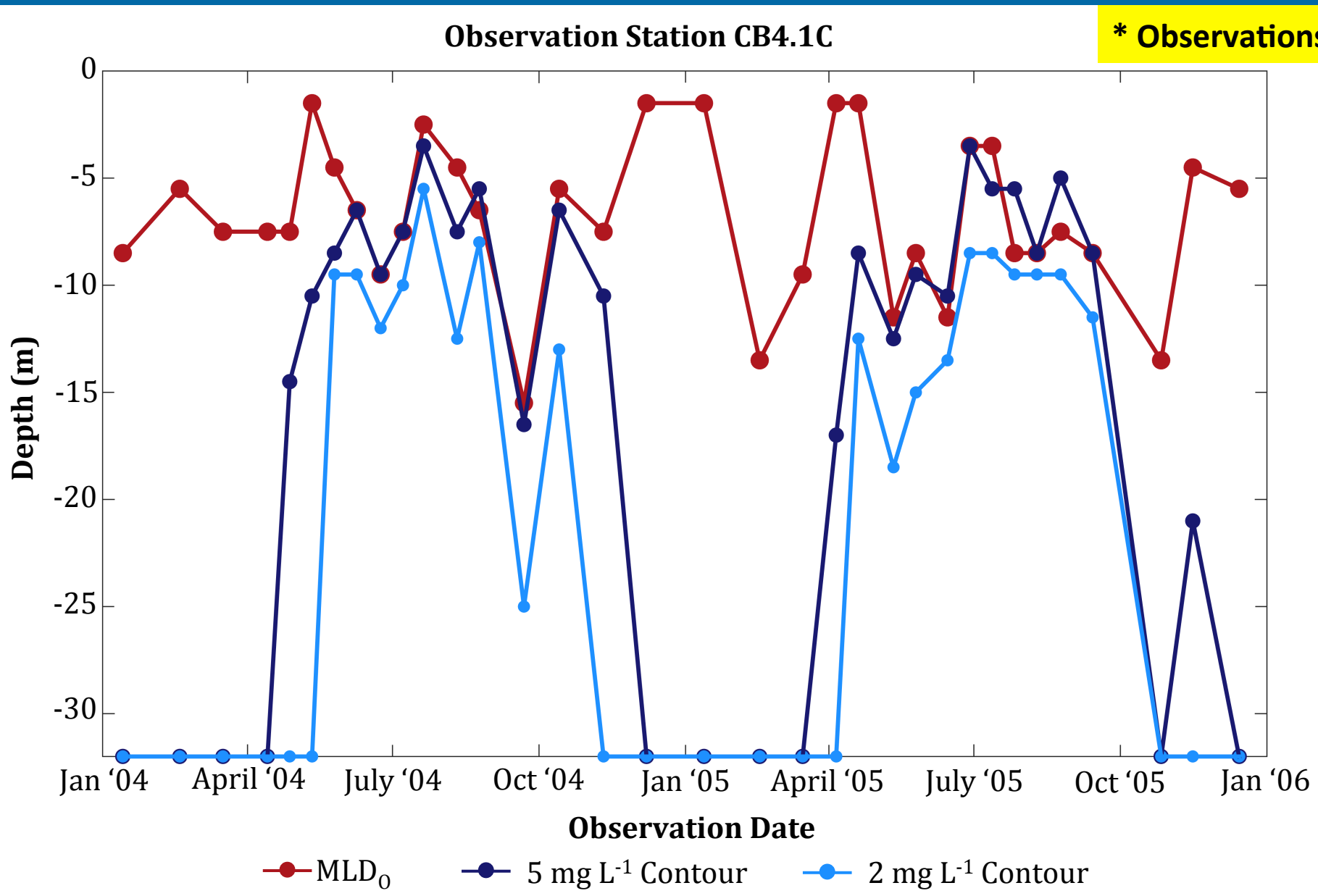

* Observations
Observation Station CB4.1C
Bottom DO (mg L-1)
12
8
4
0
2004
2005
2006
DO at MLDo (mg L-1)
14
10
6
2
2004
2005
2006
MLDo (m)
0
-5
-10
-15
-20
2004
2005
2006
Observation Date



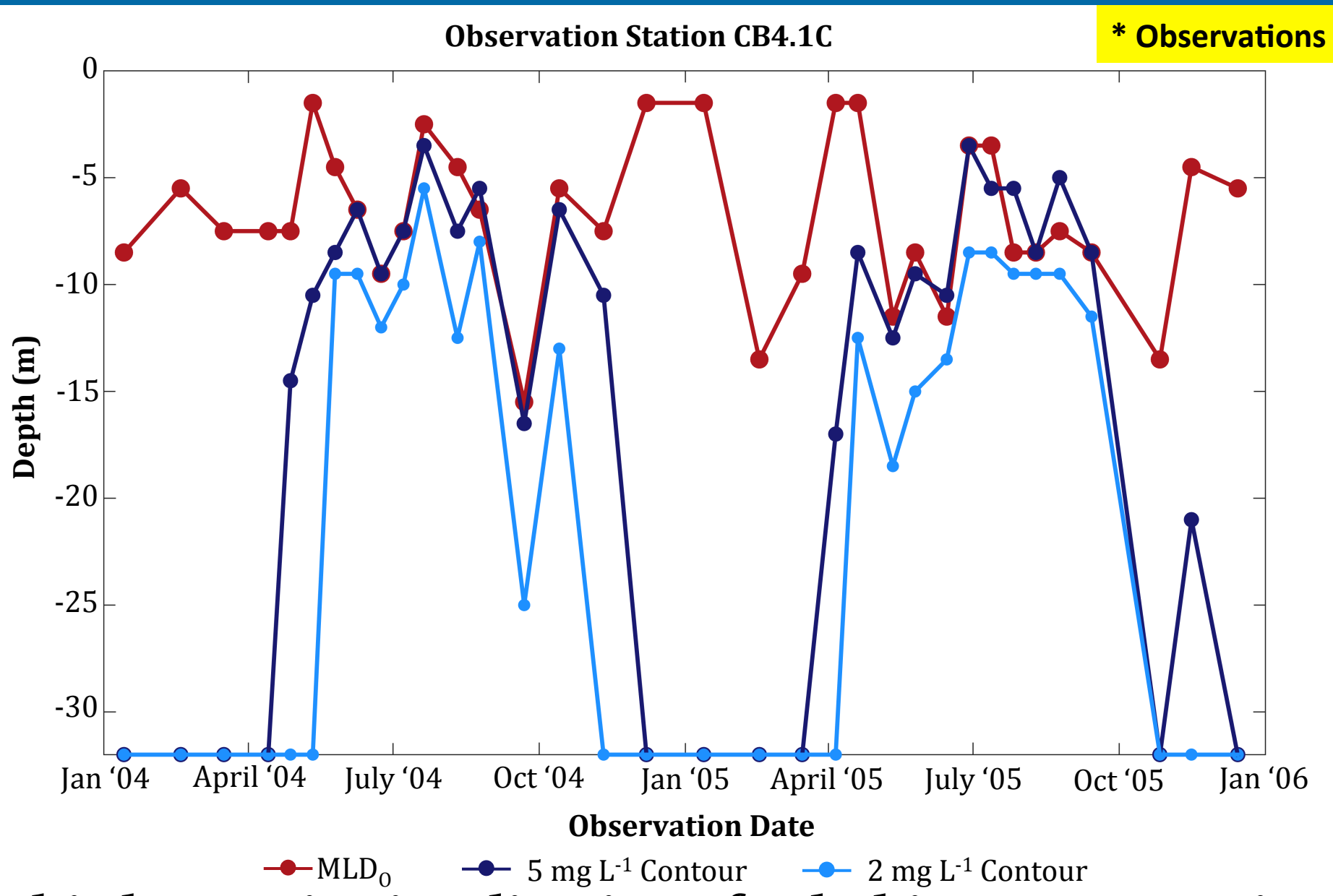
Models simulate DO better than MLDo primarily due to the pronounced seasonal cycle.

Does it matter that the models do not simulate the MLDo well?

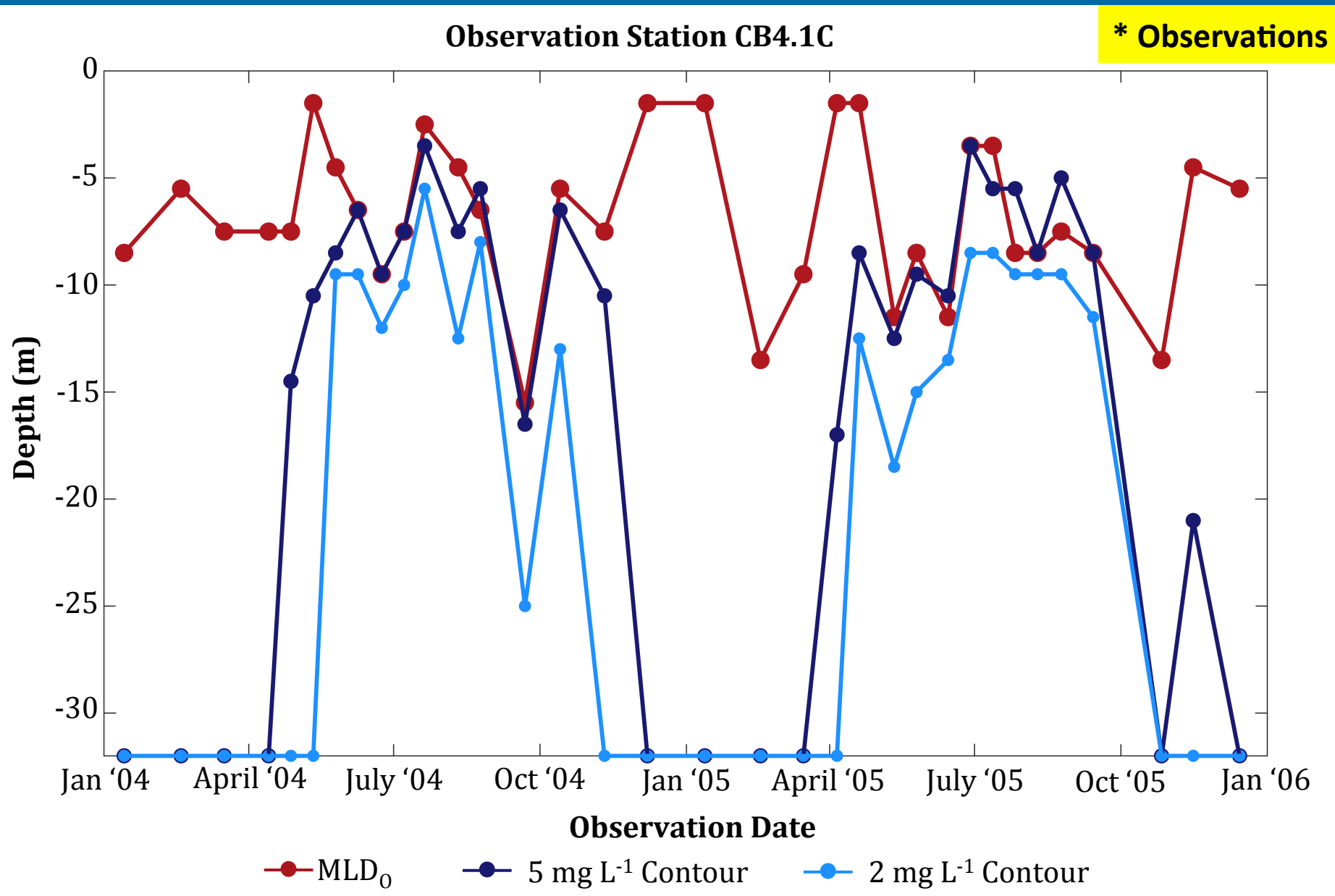

Observation Station CB4.1C
* Observations
Depth (m)
0
-5
-10
-15
-20
-25
-30
Jan '04
April '04
July '04
Oct '04
Jan '05
April '05
July '05
Oct '05
Jan '06
Observation Date
MLD0
5 mg L-1 Contour
2 mg L-1 Contour



In summer, the water column fills with low-DO water up to MLDo.



This has major implications for habitat compression throughout the Chesapeake Bay.



Important to get MLDo correct for management.

Motivating Question

How can we improve model simulations of low-oxygen conditions in the Chesapeake Bay?

Models simulate DO concentrations well.

Models do not simulate the MLDo well.

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Increased biogeochemical complexity does not seem to solve this issue

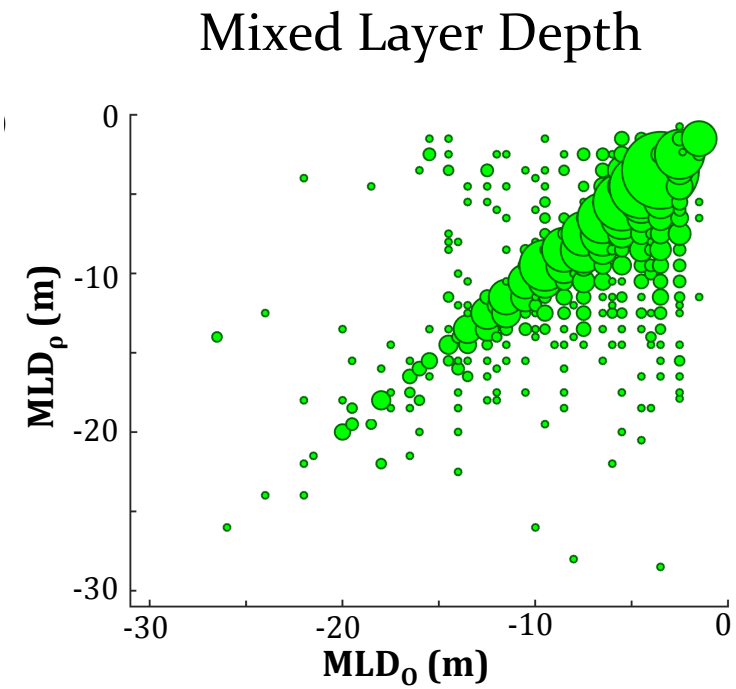
Models simulate DO concentrations well.

Models do not simulate the MLDo well.

Increased biogeochemical complexity does not seem to solve this issue

So how do we move forward?

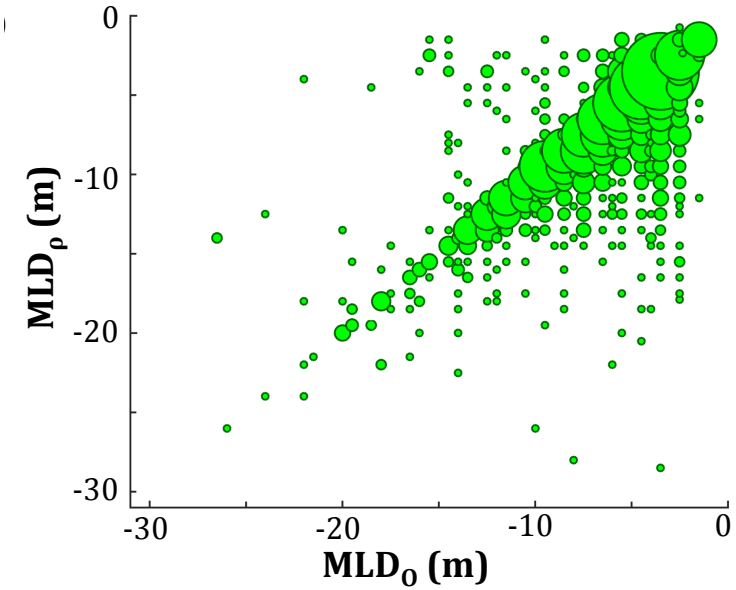
Observations for 13 Stations: 1998-2006



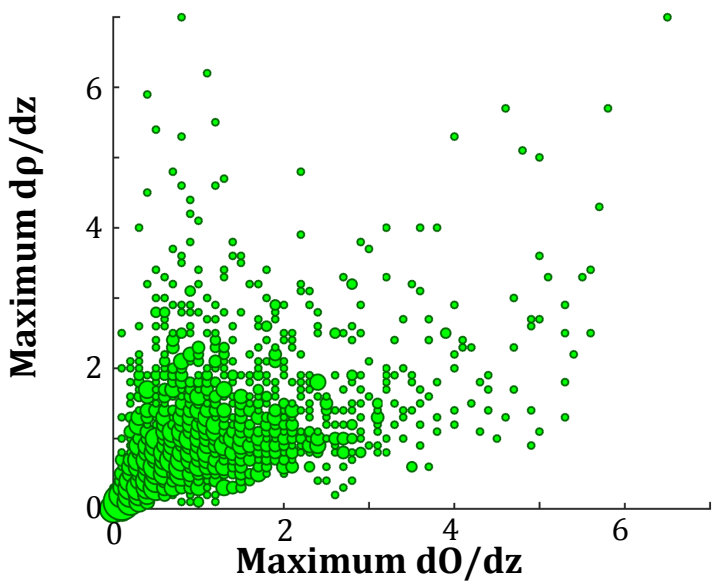
* Observations

Observations for 13 Stations: 1998-2006

Mixed Layer Depth



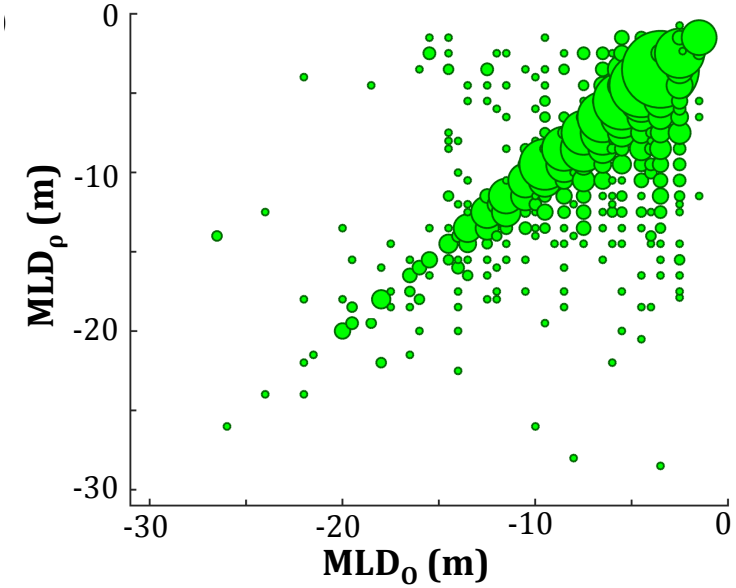
Maximum Vertical Gradient



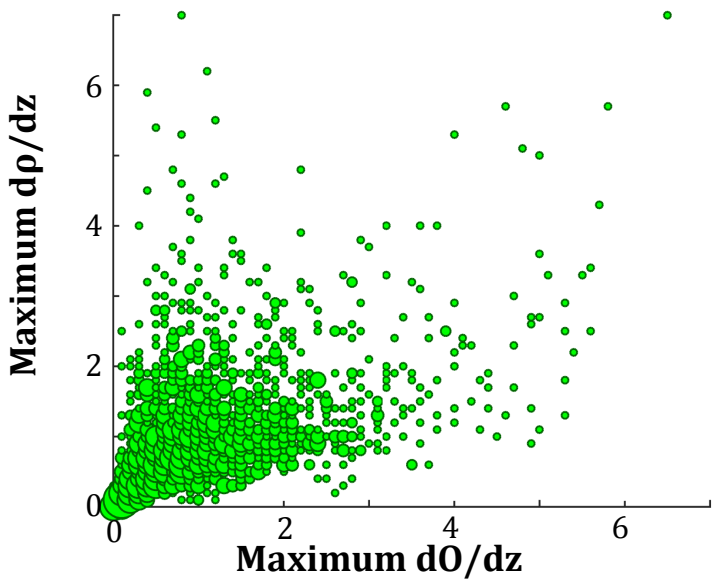
* Observations

Observations for 13 Stations: 1998-2006

Mixed Layer Depth



Maximum Vertical Gradient

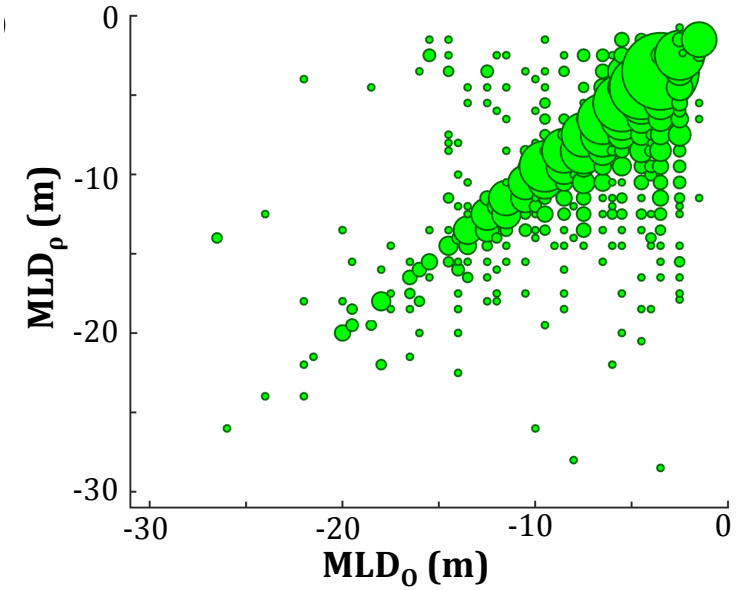


The mixed layer depths have a much stronger relationship than the actual degrees of stratification.

* Observations

Observations for 13 Stations: 1998-2006

Mixed Layer Depth



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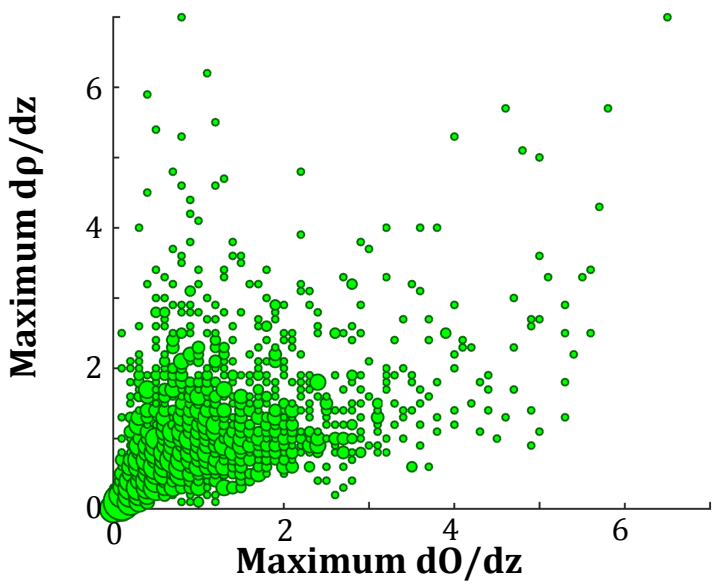
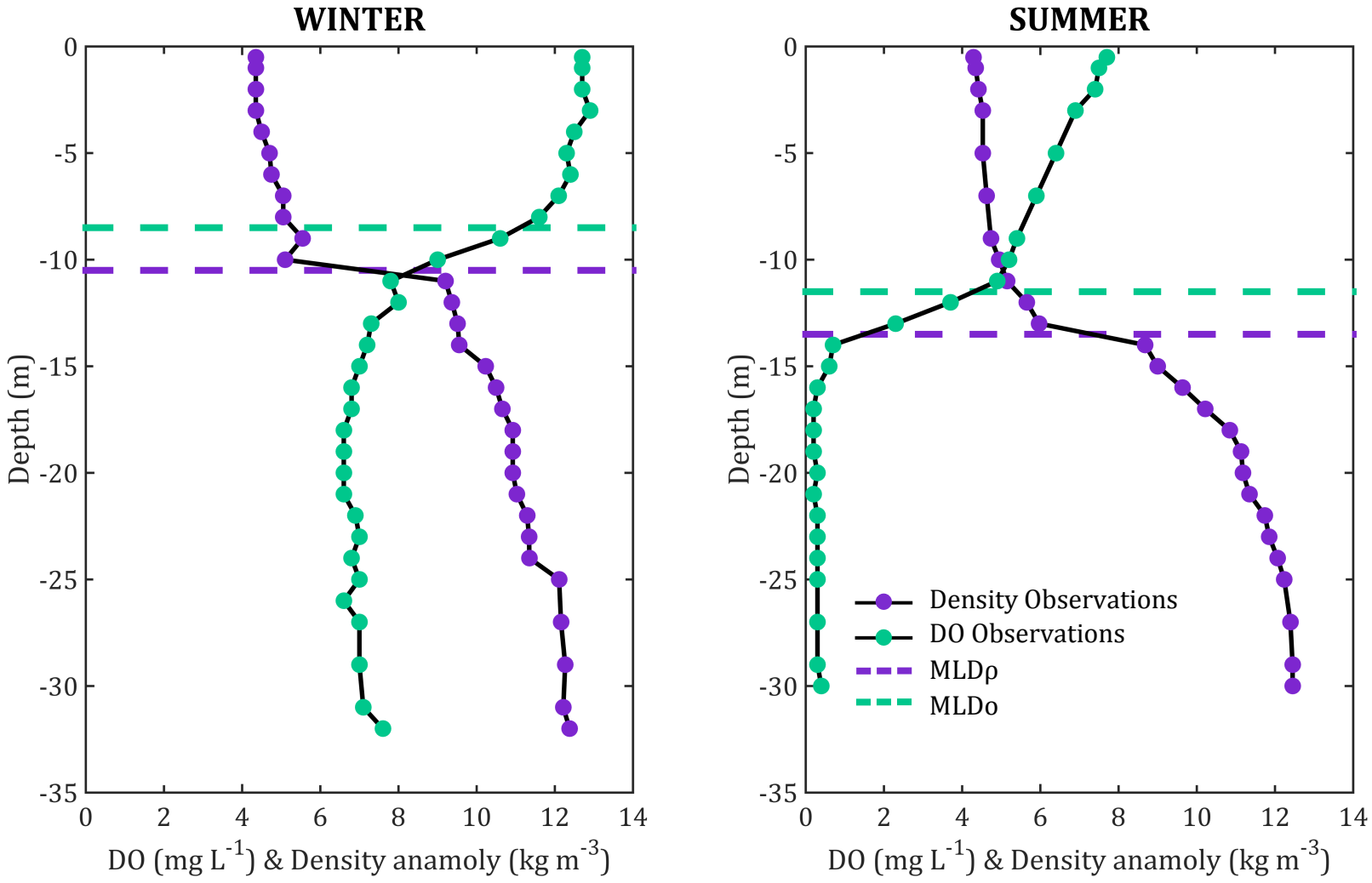


The mixed layer depths have a much stronger relationship than the actual degrees of stratification.

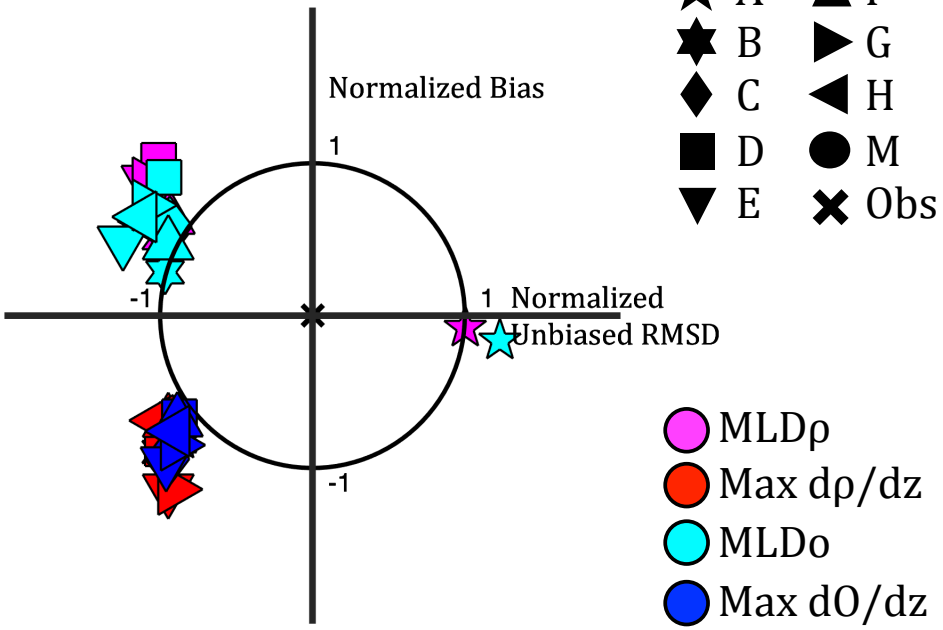
It is not the vertical gradient*, but the location of the MLD that is important.

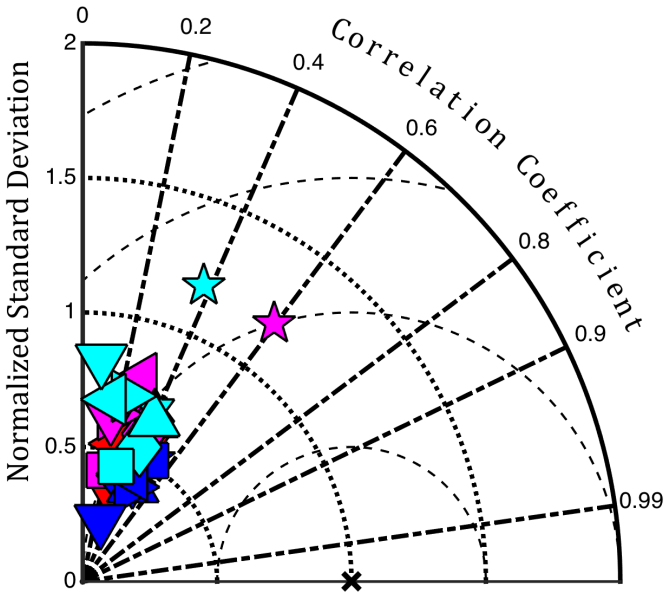
* Observations

Station CB4.1C



Stratification





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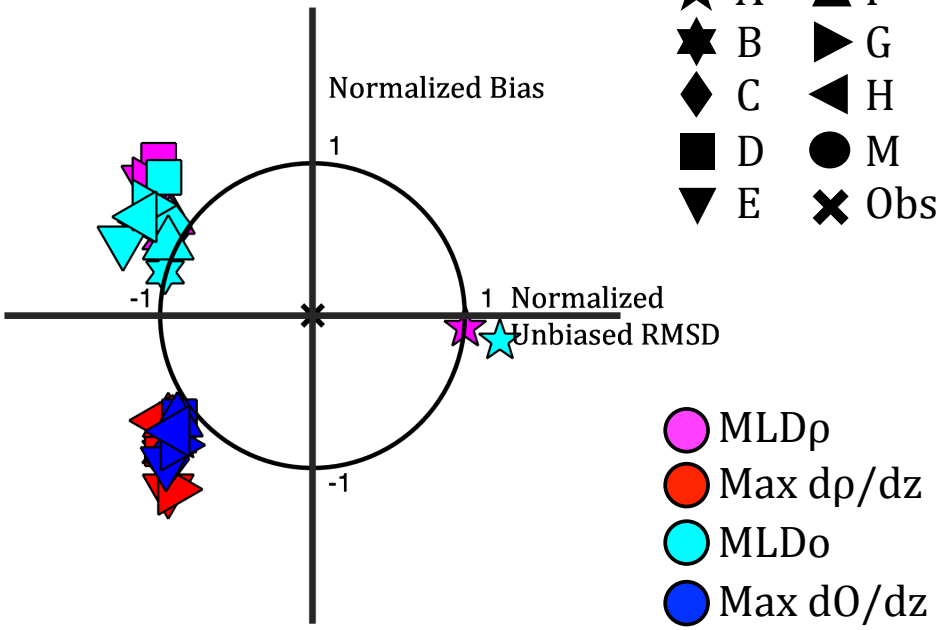

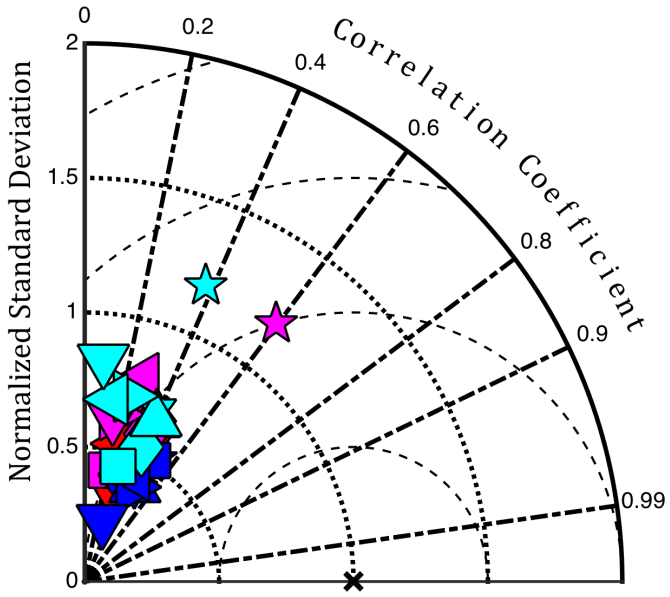

MLDρ
Max dρ/dz
MLDo
Max dO/dz

Increased skill of MLDρ → increased skill of MLDo

Conclusions

- All models do well in terms of bottom DO
  - Independent of biogeochemical complexity
  - Model Mean performs best

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  - Model Mean performs best
- Models do not simulate MLDo well
  - Important to management because of its impact on habitat compression

Conclusions

- All models do well in terms of bottom DO
  - Independent of biogeochemical complexity
  - Model Mean performs best
- Models do not simulate MLDo well
  - Important to management because of its impact on habitat compression
- Better physics is needed to solve the issue
  - The location of the density mixed layer depth is more important to correctly simulate than the degree of the vertical gradient

Thank You

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www.biogeosciences-discuss.net/12/20361/2015/
doi:10.5194/bgd-12-20361-2015

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