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Intercomparison of 3-D models for estuarine hydrodynamics and hypoxia within the US IOOS Super-Regional Coastal Modeling Testbed

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The Estuarine Hypoxia Team

U.S. IOOS Coastal Ocean Modeling Testbed

Intercomparison of 3-D Models for Estuarine Hydrodynamics and Hypoxia

Carl Friedrichs, Marjy Friedrichs, Aaron Bever
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And the US IOOS Estuarine Hypoxia Testbed Team

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92nd Annual American Meteorological Society Meeting

Intercomparison of 3-D Models for Estuarine Hydrodynamics and Hypoxia

Overarching Goal:

To help improve process-based, operational and scenario-based modeling of hypoxia in Chesapeake Bay

Estuarine Hypoxia Team:

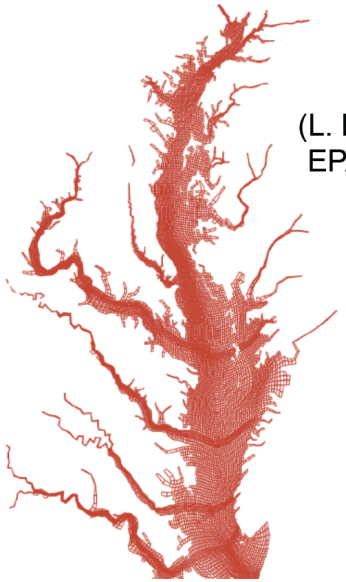
Aaron Bever (VIMS)
Carl Cerco (USACE)
Carl Friedrichs (VIMS)
Marjorie Friedrichs (VIMS)
David Green (NOAA-NWS)
Raleigh Hood (UMCES)
Lyon Lanerolle (NOAA-CSDL)
Ming Li (UMCES)
Lew Linker (EPA)
Wen Long (UMCES)
Scott Peckham (CSDMS)
Malcolm Scully (ODU)
Kevin Sellner (CRC)
Jian Shen (VIMS)
John Wilkin (Rutgers U.)
Doug Wilson (NOAA-NCBO)

Intercomparison of 3-D Models for Estuarine Hydrodynamics and Hypoxia

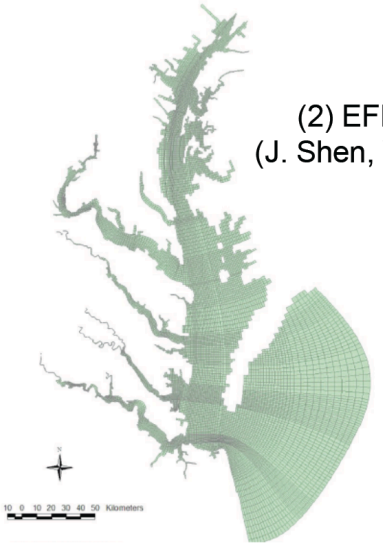
Outline:

- **Methods: (i) Models, (ii) observations, (iii) skill metrics**
- Results (i): What is the relative hydrodynamic skill of these CB models?
- Results (ii): What is the relative dissolved oxygen skill of these CB models?
- Summary and Conclusions

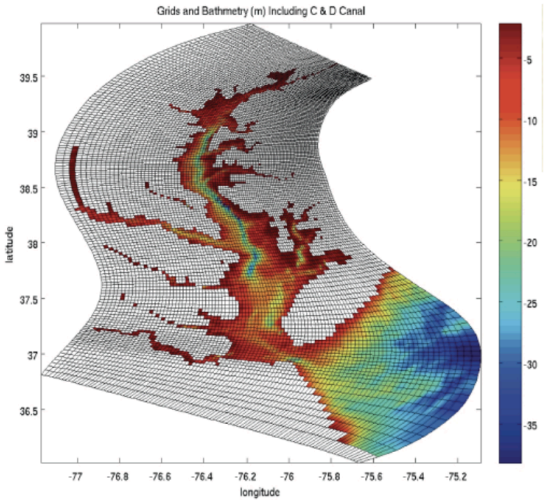
Methods (i) Models: 5 Hydrodynamic Models (so far)



(1) CH3D
(L. Linker/C. Cerco,
EPA/USACE CBP)

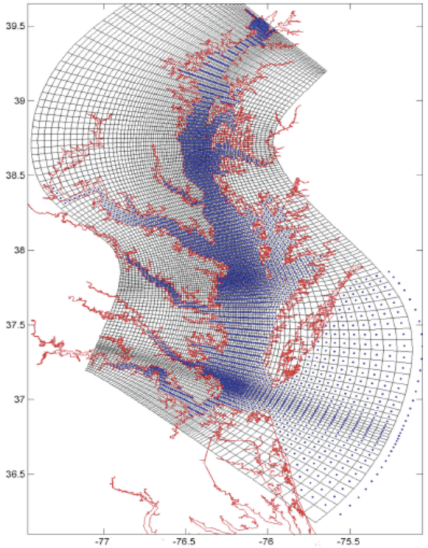


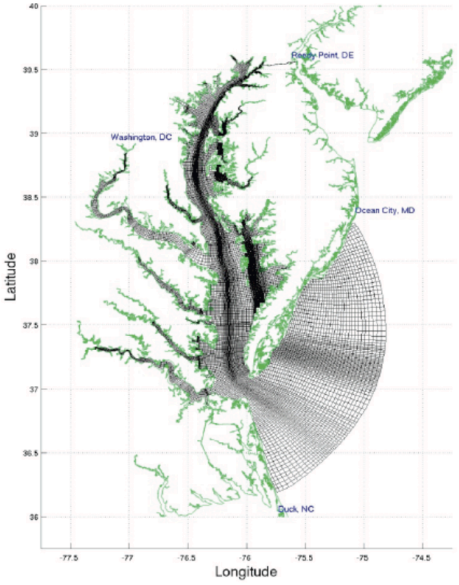
(2) EFDC
(J. Shen, VIMS)



(3) ChesROMS
(R. Hood/W. Long, UMCES)

(4) UMCES ROMS
(M. Li/Y. Li, UMCES)





(5) CBOFS2
(L. Lanerolle, NOAA-CSDL)

Additional Candidates:

ADH
ECOM
ELCIRC
FVCOM
SELFE

Methods (i) Models (cont.): 5 Dissolved Oxygen Models (so far)

- ICM: CBP model; complex biology
- bgc: NPZD-type biogeochemical model
- 1eqn: Simple one equation respiration (includes SOD)
- 1term-DD: depth-dependent net respiration
  (not a function of x, y, temperature, nutrients…)
- 1term: Constant net respiration

Methods (i) Models (cont.): 8 Multiple combinations (so far)

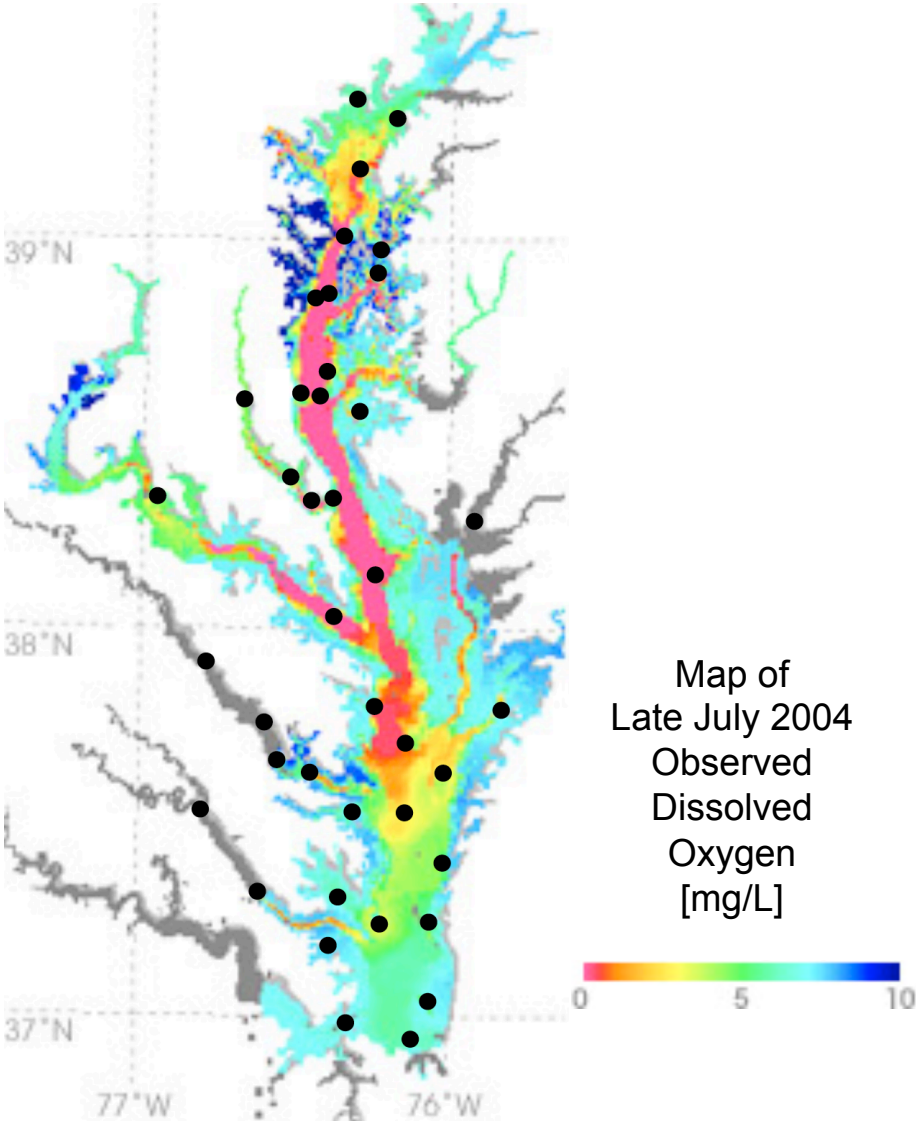
CH3D	+	ICM
EFDC	+	1eqn, 1term
CBOFS2	+	1term, 1term+DD
ChesROMS	+	1term, 1term+DD, bgc

Methods (ii) observations: S and DO from Up to 40 CBP station locations

Data set for model skill assessment:

~ 40 EPA Chesapeake Bay stations
Each sampled ~ 20 times in 2004

Temperature, Salinity,
Dissolved Oxygen



(http://earthobservatory.nasa.gov/Features/ChesapeakeBay)

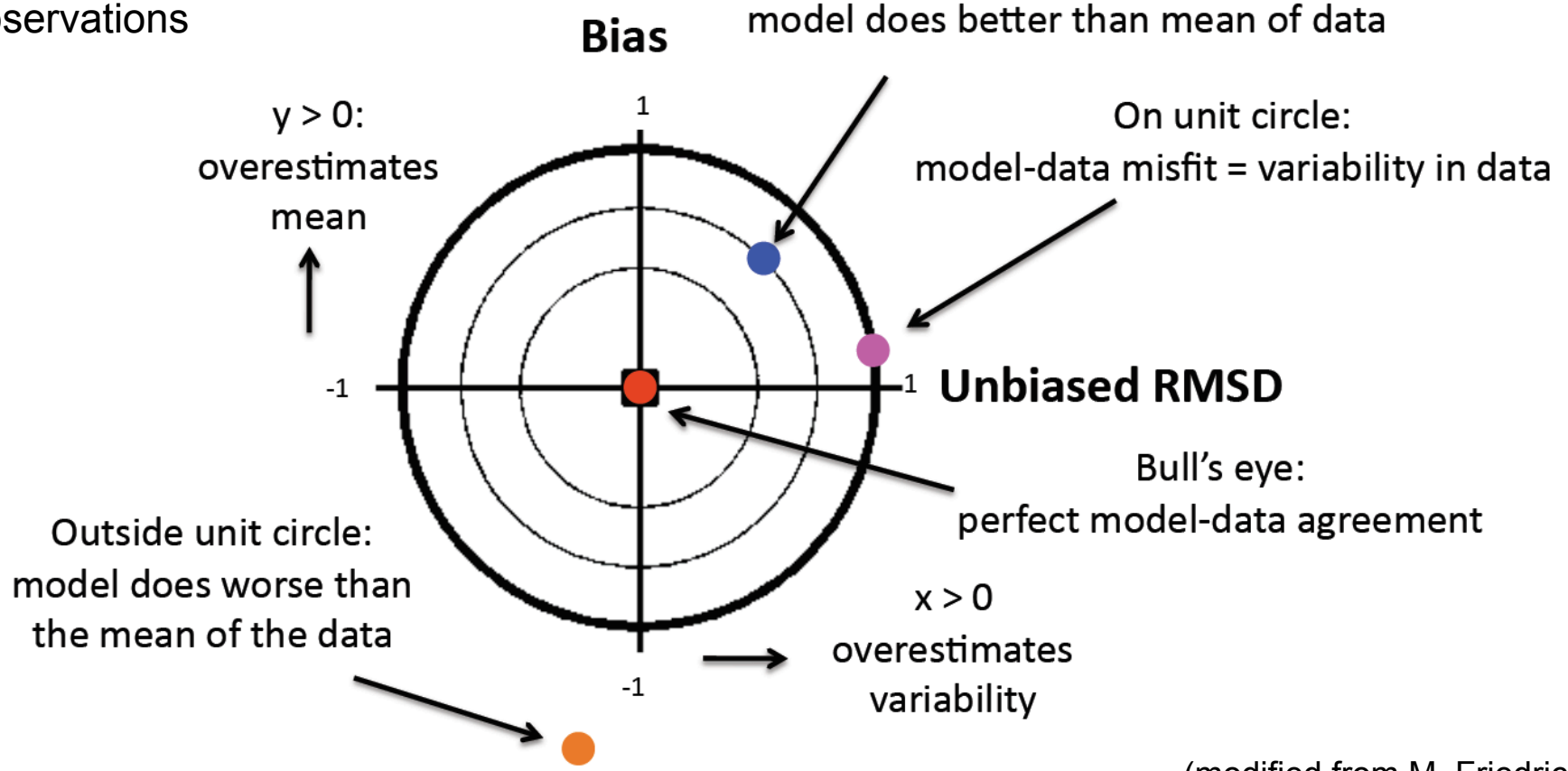
Methods (iii) Skill Metrics: Target diagram

$$\text{Total RMSD}^2 = \text{Bias}^2 + \text{unbiased RMSD}^2$$

mean

variability

Dimensionless version of plot normalizes by standard deviation of observations



(modified from M. Friedrichs)

Intercomparison of 3-D Models for Estuarine Hydrodynamics and Hypoxia

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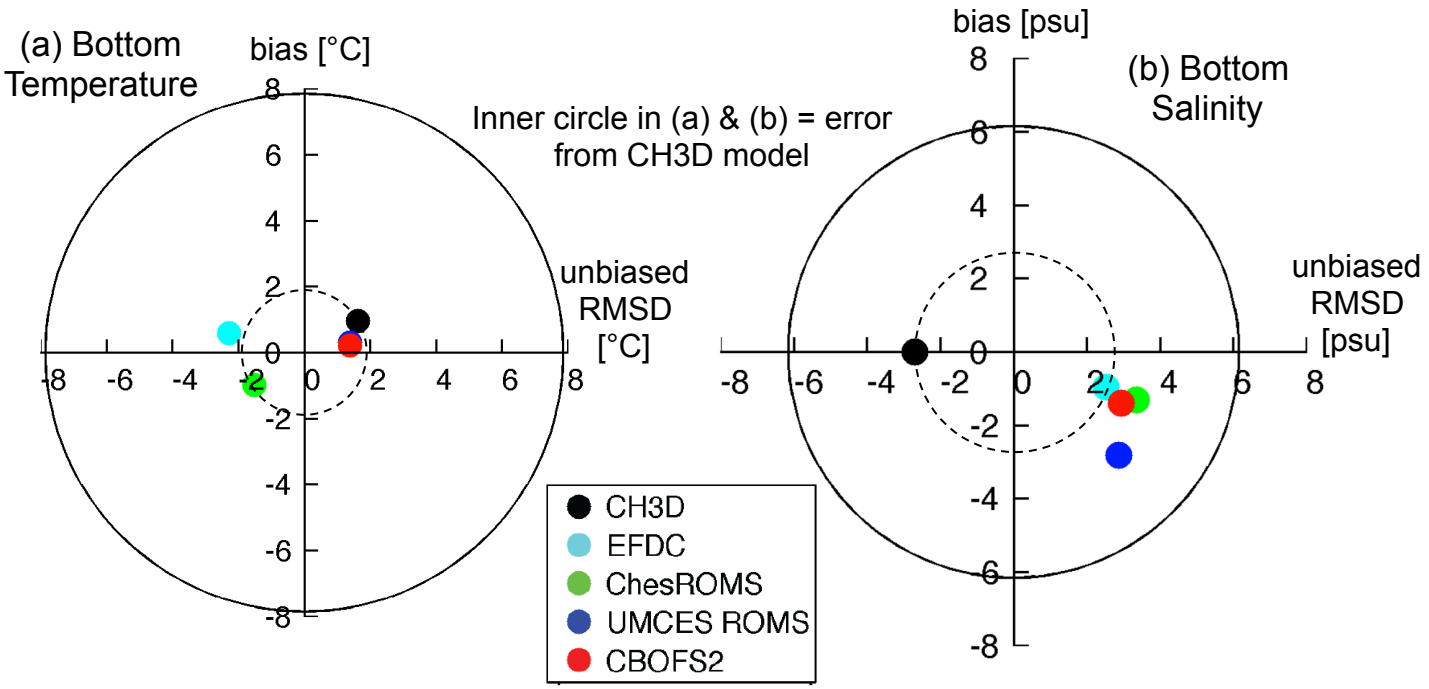
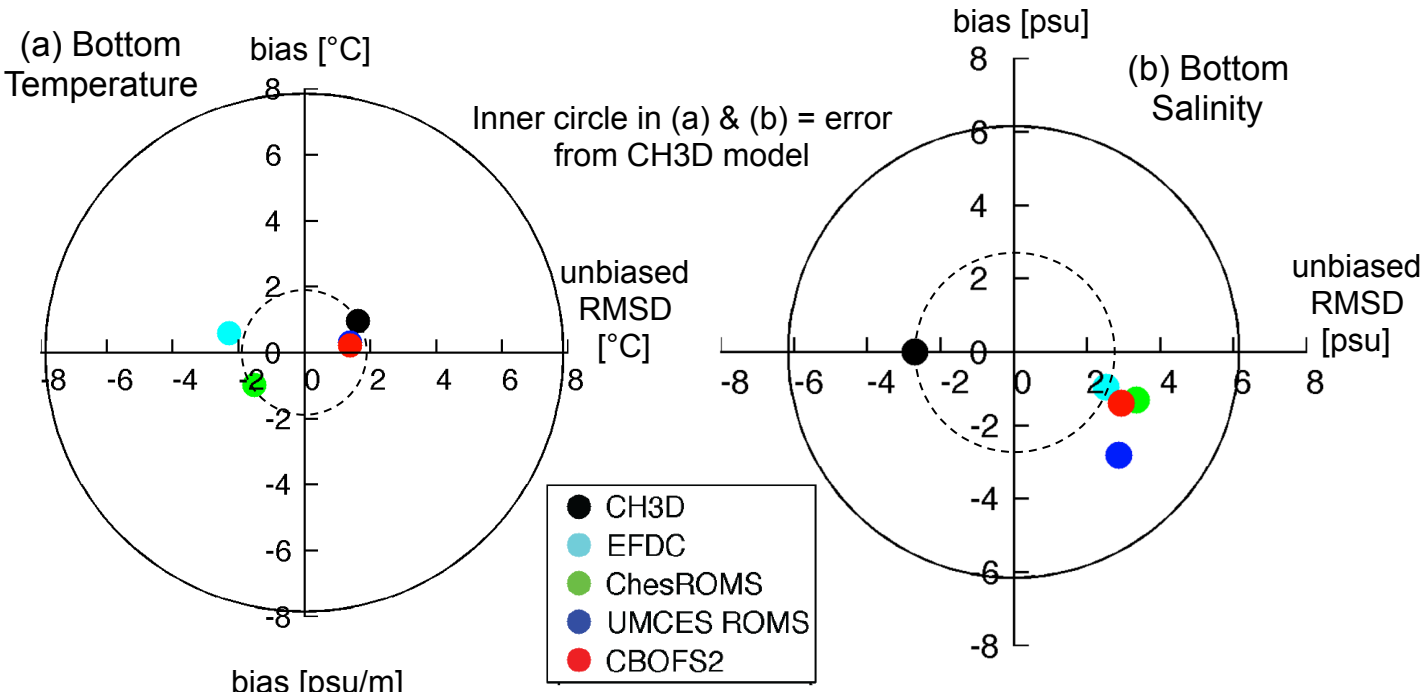
Results (i): Hydrodynamic Model Comparison

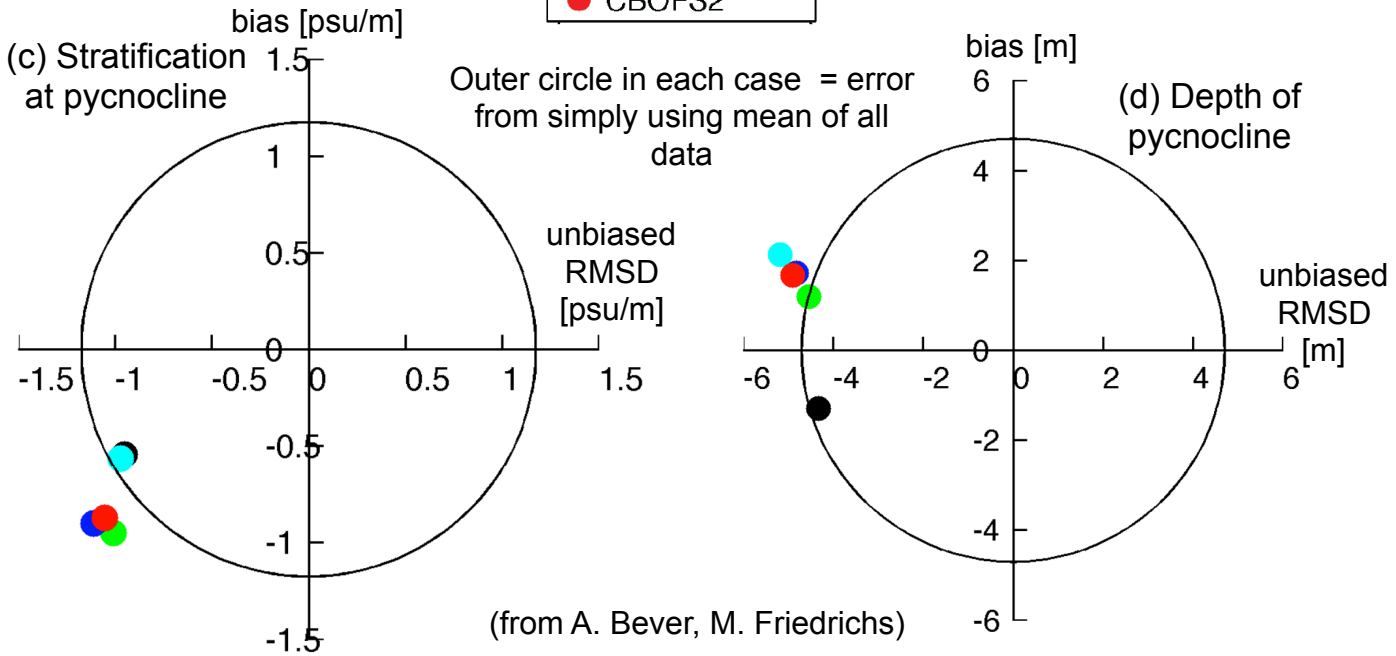


- All models do very well hind-casting temperature.

- All do well hind-casting bottom salinity with CH3D and EFDC doing best.

Results (i): Hydrodynamic Model Comparison





(from A. Bever, M. Friedrichs)

- All models do very well hind-casting temperature.

- All do well hind-casting bottom salinity with CH3D and EFDC doing best.

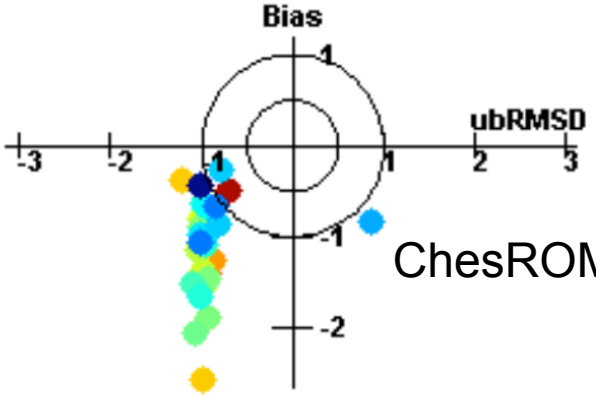
- Stratification is a challenge for all the models.

- All underestimate strength and variability of stratification with CH3D and EFDC doing slightly better.

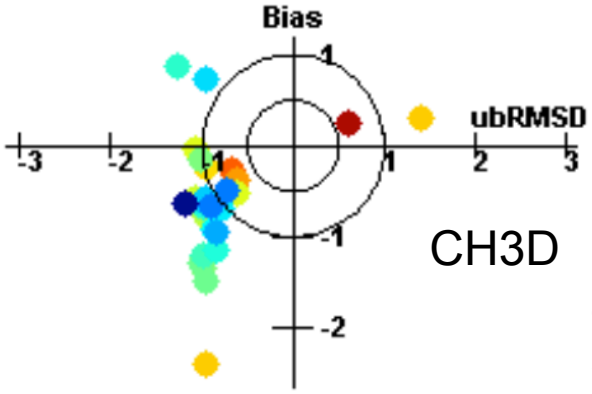
- CH3D and ChesROMS do slightly better than others for pycnocline depth, with CH3D too deep, and the others too shallow.

- All underestimate variability of pycnocline depth.

Results (i) Hydrodynamics: Temporal variability of stratification at 40 stations

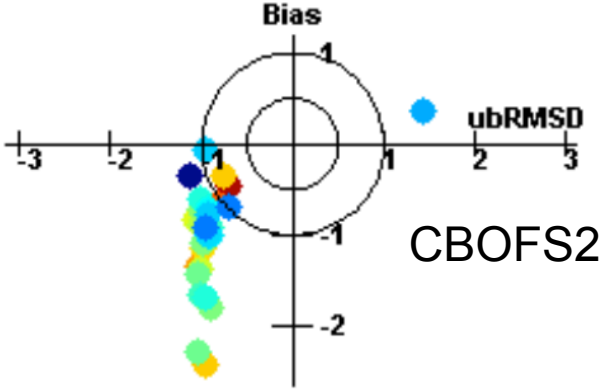


ChesROMS

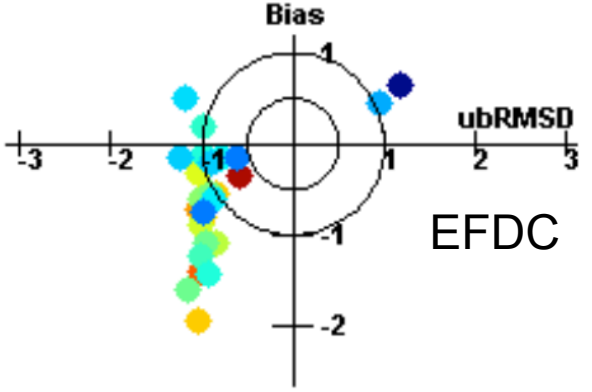


CH3D

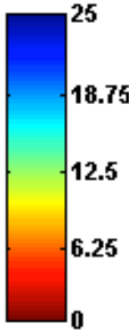
- Model behavior for stratification is similar in terms of temporal variation of error at individual stations



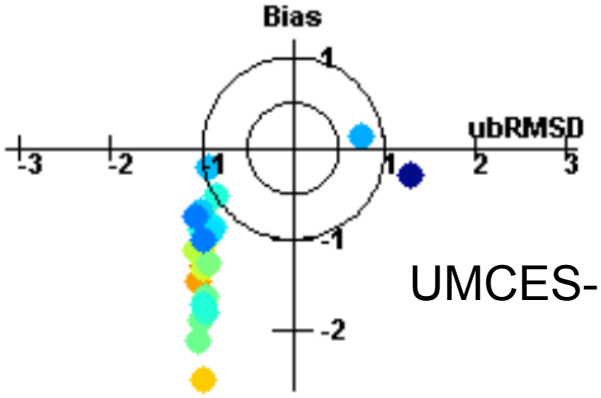
CBOFS2



EFDC



Mean salinity of individual stations [psu]



UMCES-ROMS

(from A. Bever, M. Friedrichs)

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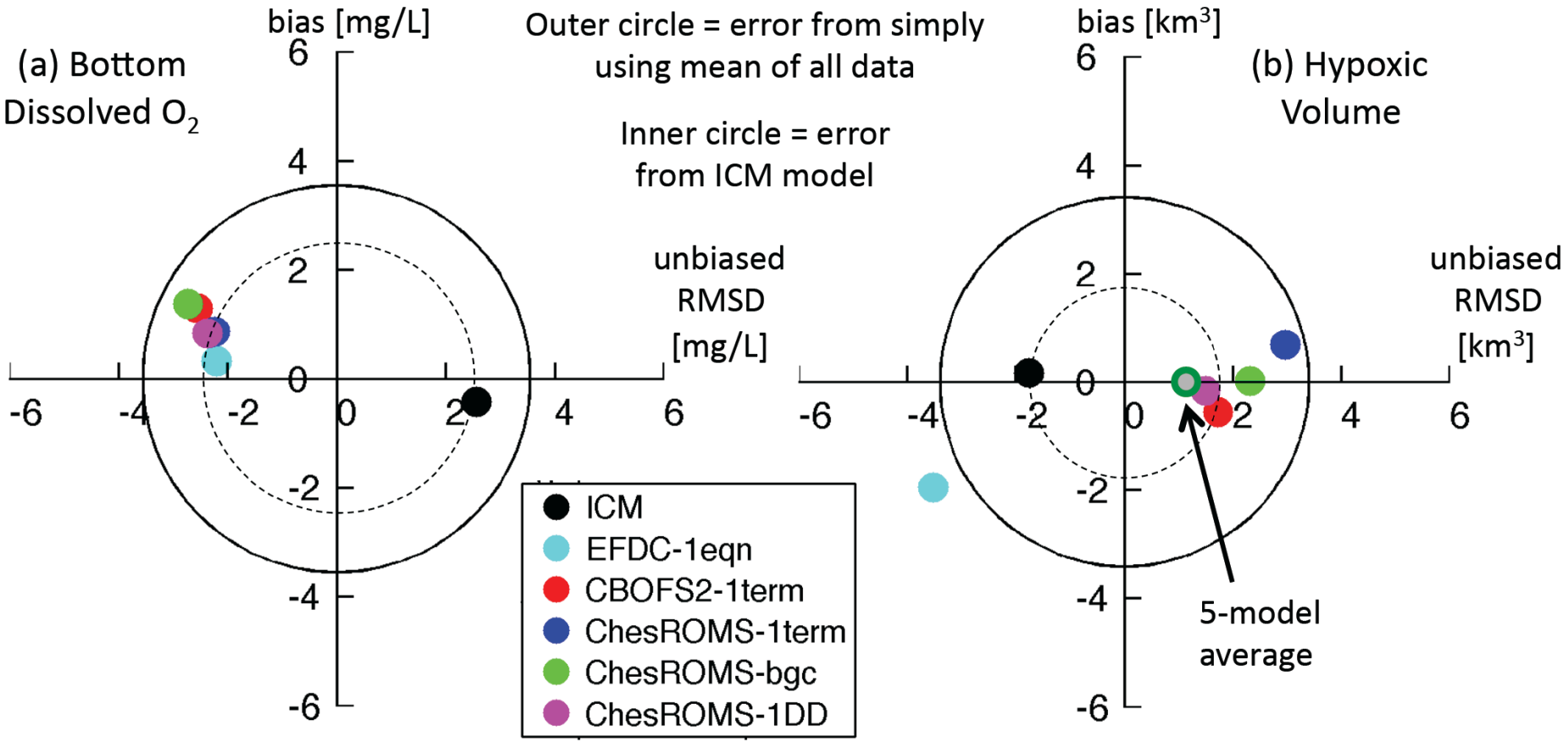
Results (ii): Dissolved Oxygen Model Comparison



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- A five-model average does better than any one model alone.

(from A. Bever, M. Friedrichs)

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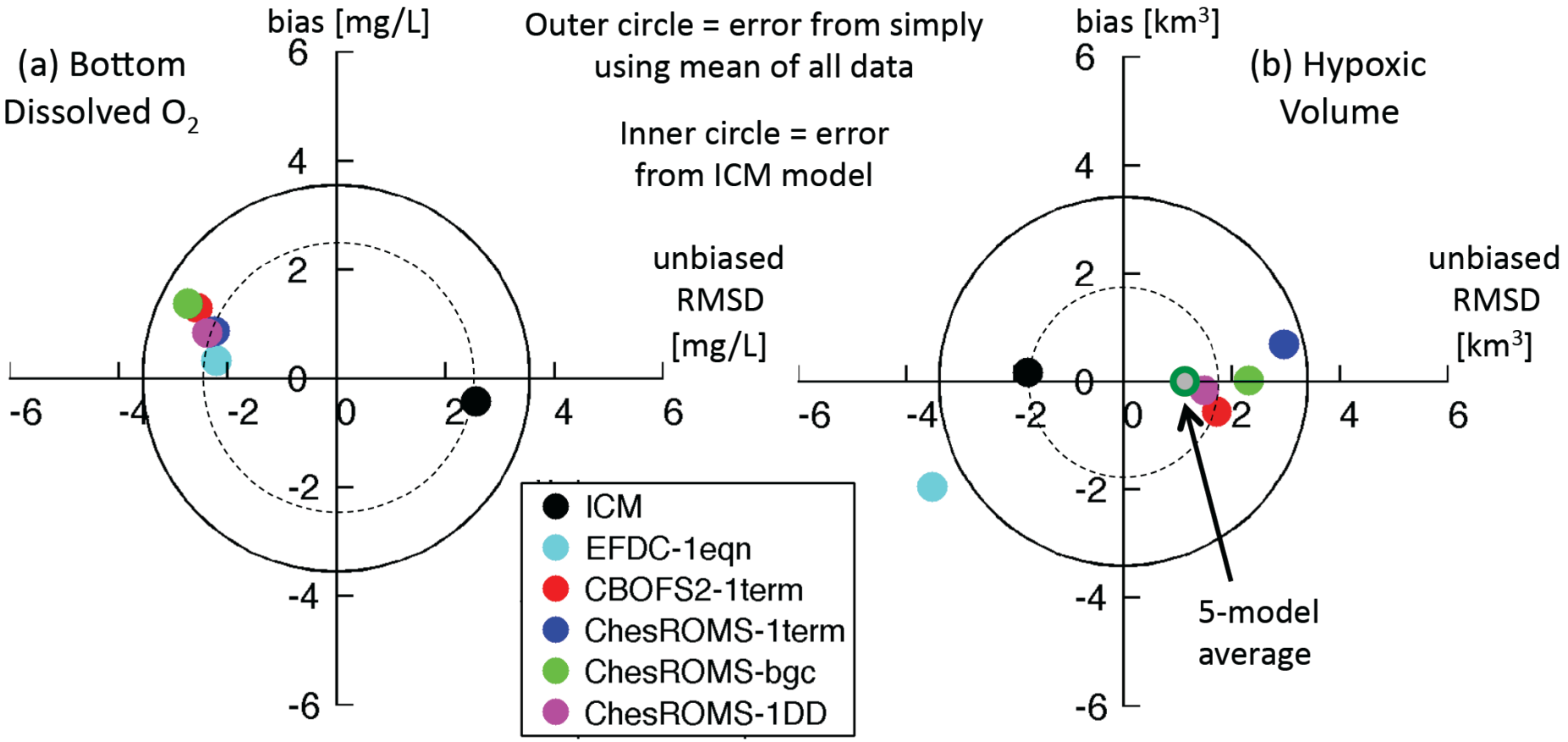

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TAKE HOME MESSAGE

(from A. Bever, M. Friedrichs)

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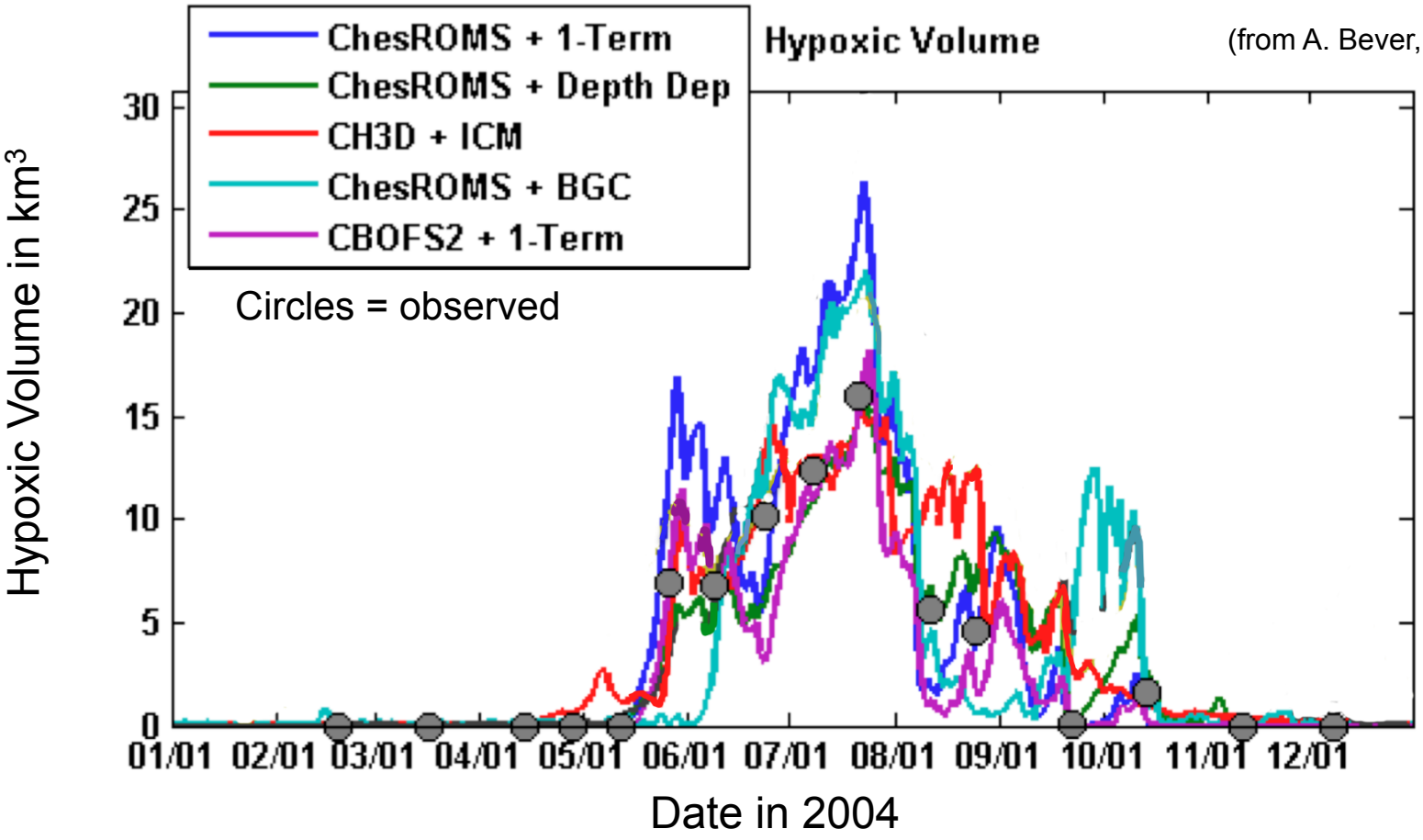

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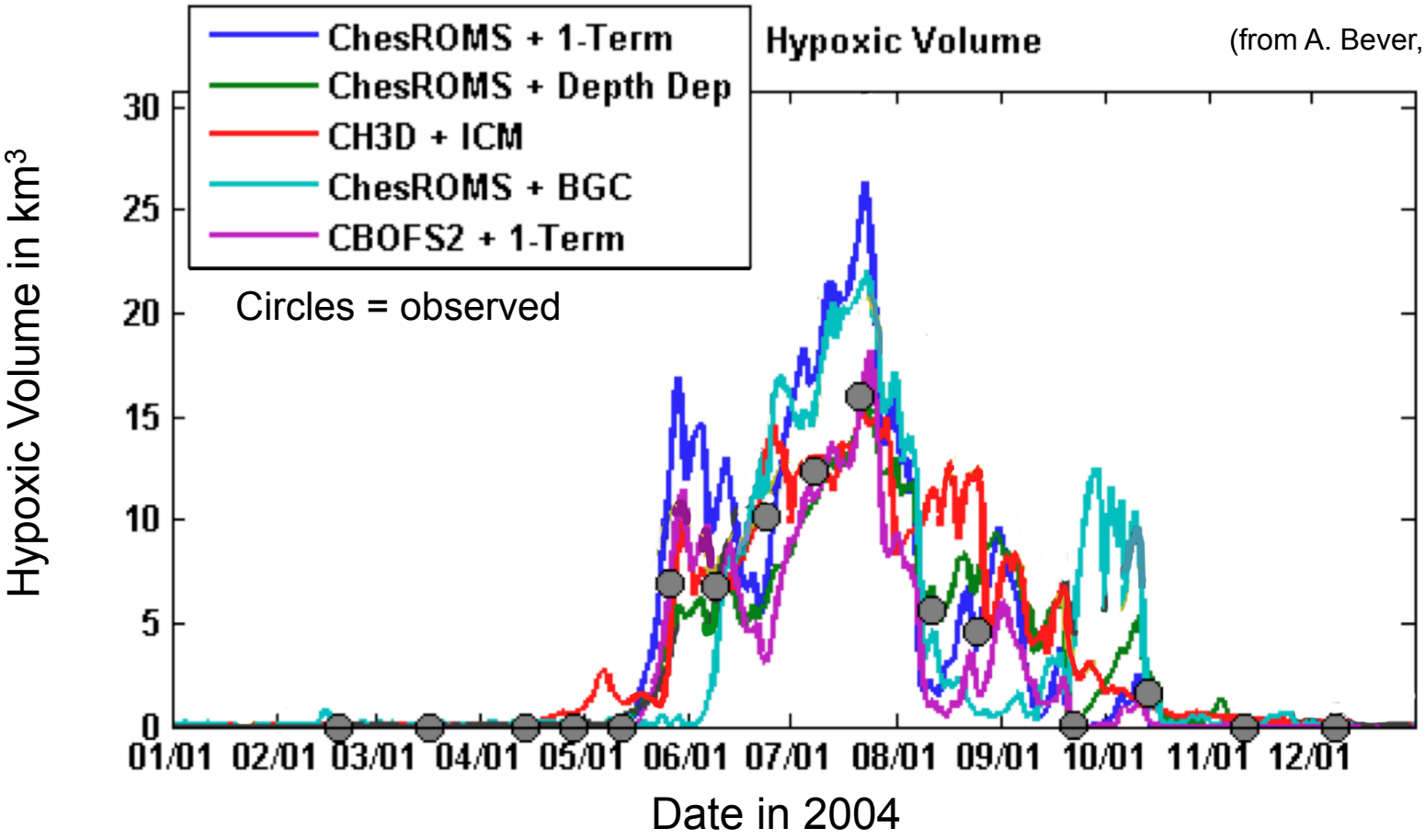
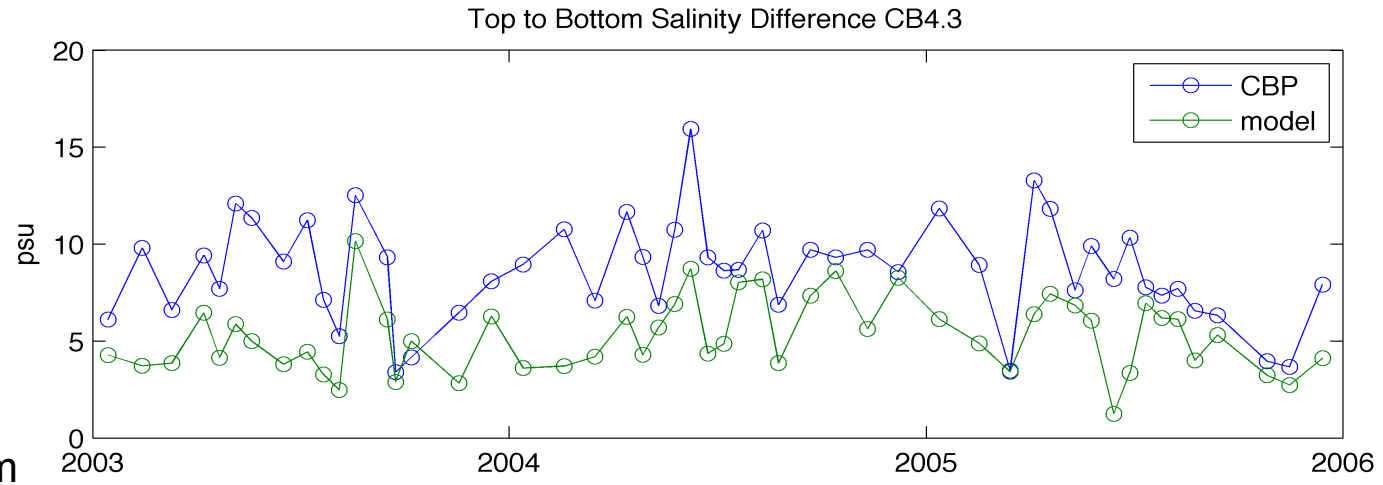


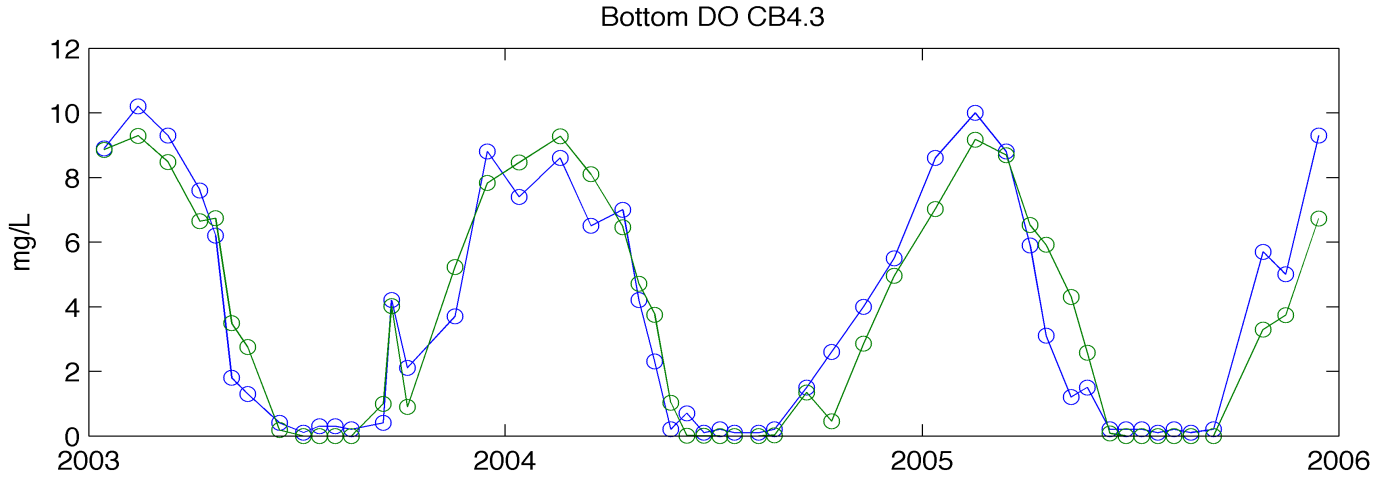
- A five-model average does better than any one model alone.

- EPA should use multiple models in their scenario forecasts.

Results (ii) Dissolved Oxygen: Top-to-Bottom ΔS and Bottom DO in Central Chesapeake Bay

ChesROMS-1term model





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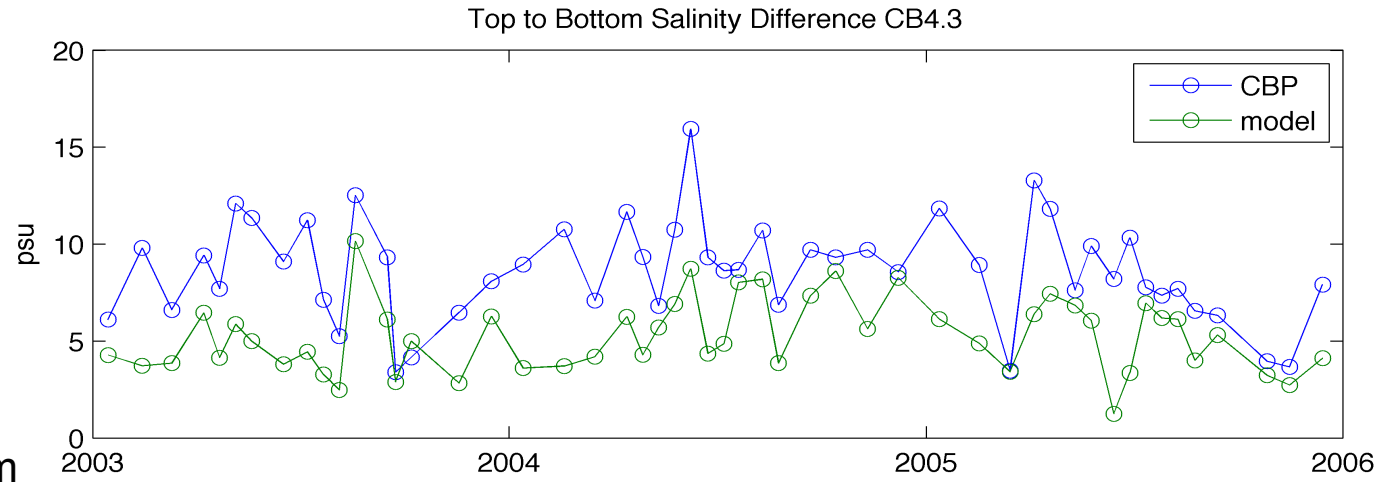
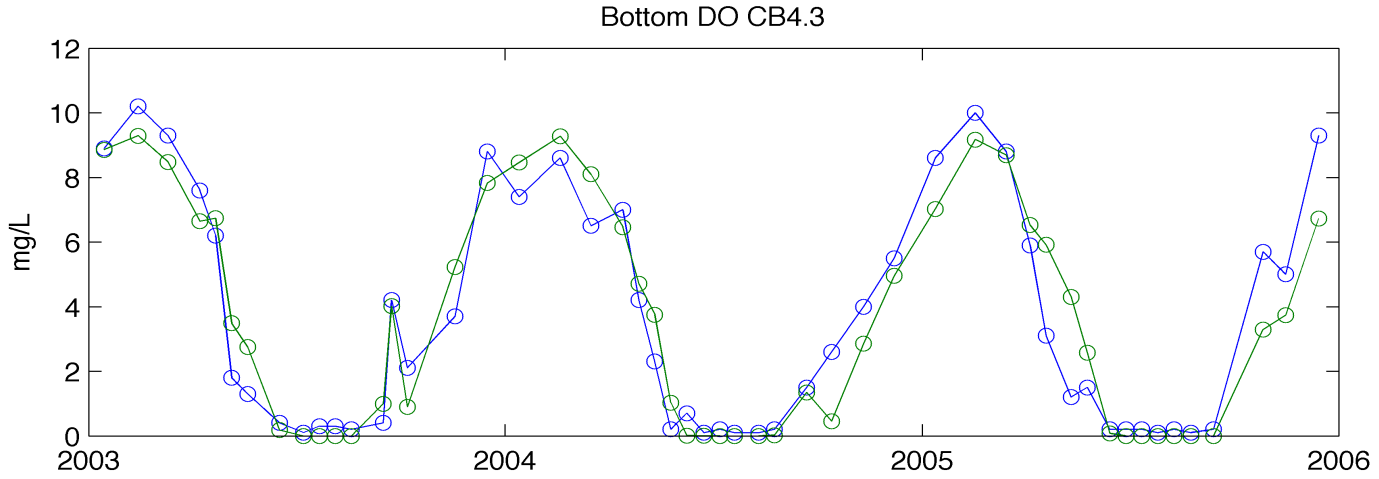


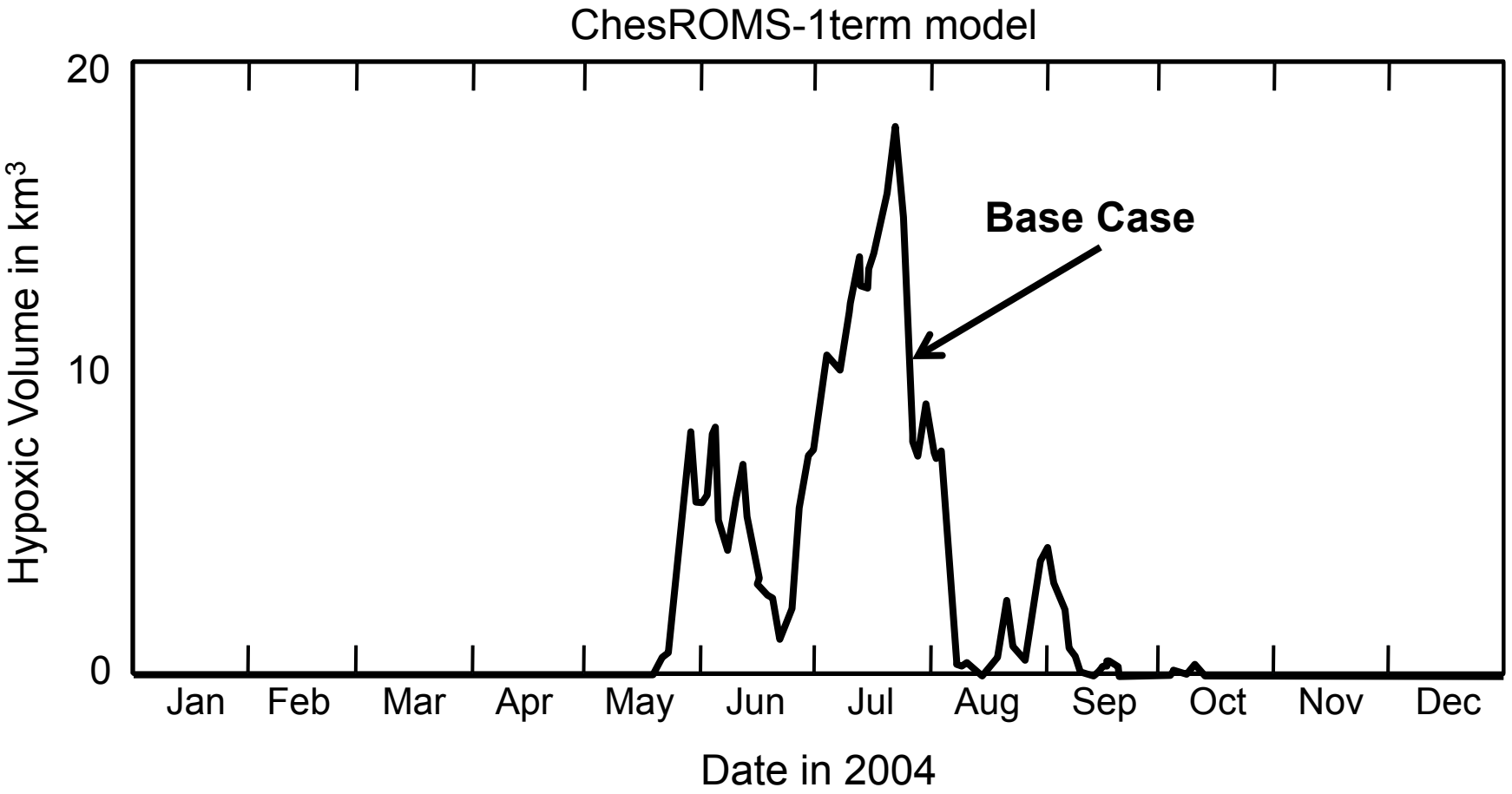


- All models reproduce DO better than they reproduce stratification.

- So if stratification is not controlling DO, what is?

(by M. Scully)

Results (ii) (cont.): Effect of Physical Forcing on Dissolved Oxygen



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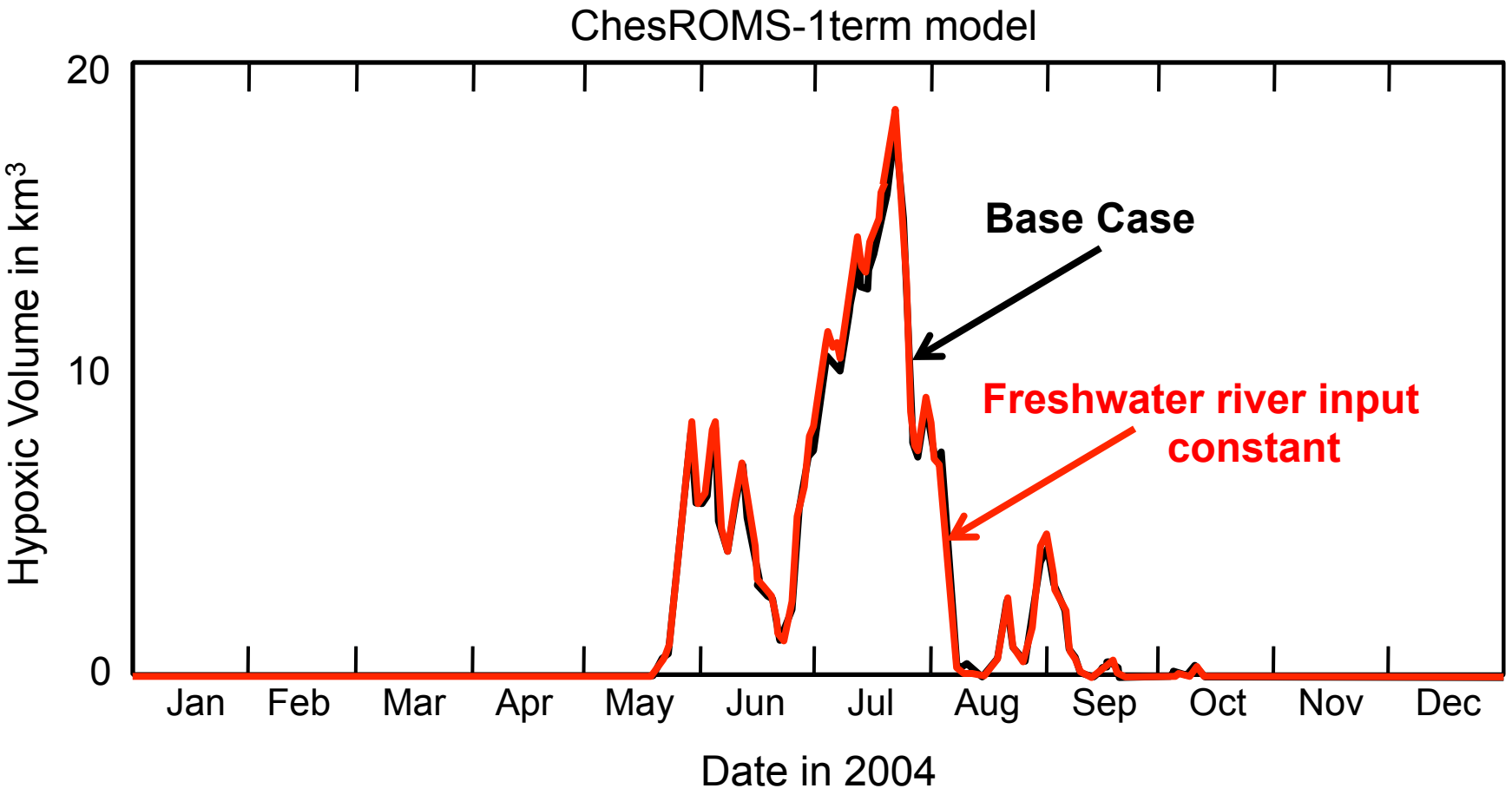

Seasonal changes in hypoxia are not a function of seasonal changes in freshwater.

(by M. Scully)

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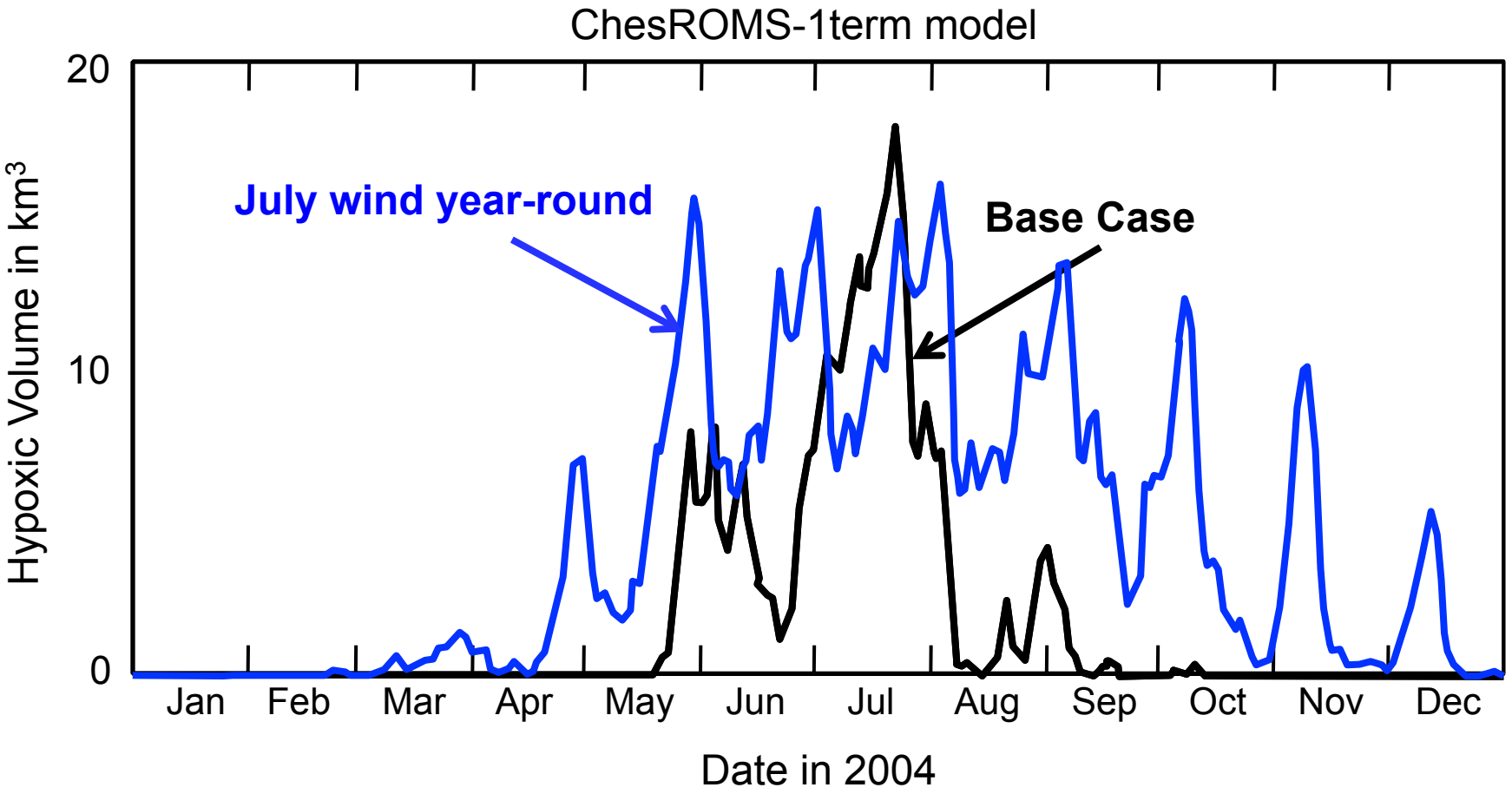

Seasonal changes in hypoxia may be largely due to seasonal changes in wind.

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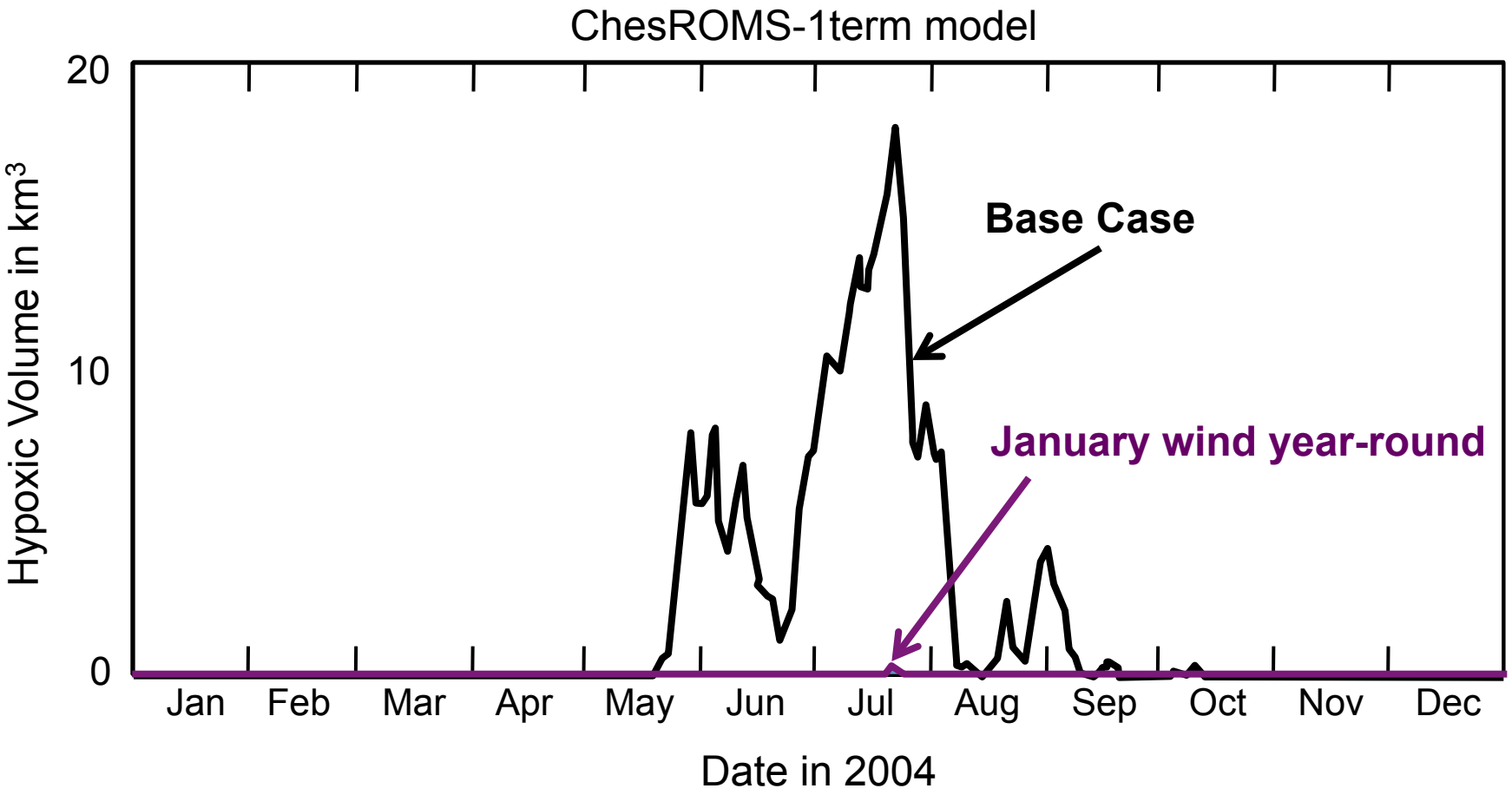

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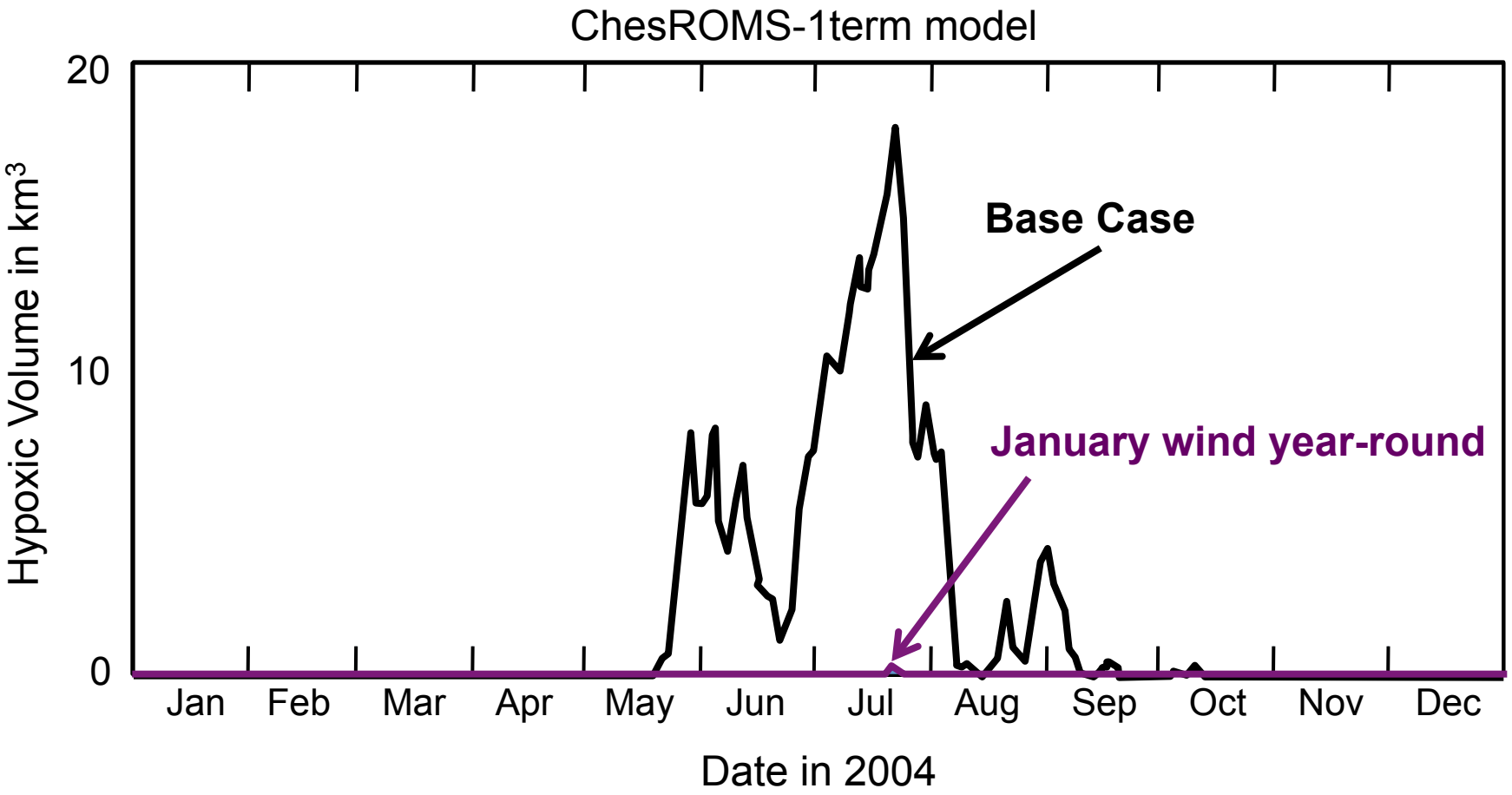

Seasonal changes in hypoxia may be largely due to seasonal changes in wind.

- Since NOAA can forecast wind, NOAA can forecast hypoxia.

(by M. Scully)

Intercomparison of 3-D Models for Estuarine Hydrodynamics and Hypoxia

Summary & Conclusions:

- Available models generally have similar skill in terms of hydrodynamic quantities.
- Simple models reproduce dissolved oxygen (DO) and hypoxic volume about as well as more complex models.
- All models reproduce DO better than they reproduce stratification.
- A five-model average does better than any one model alone.
- Seasonal cycle in DO/hypoxia is due more to wind speed and direction than to seasonal cycle in freshwater input, stratification, nutrient input or respiration.
  - Note: This does **not** mean than inter-annual variation in nutrient input is unimportant.

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- Key guidance for NOAA operational forecasting – Short-term forecasting of hypoxia in Chesapeake Bay built on wind forecasting is likely to work.

- Key guidance for EPA scenario forecasting – Long-term scenario forecasting of hypoxia in Chesapeake Bay will be more reliable when averaging multiple models.