Assessment Options Support: Lessons From Model Assessments of Bay Monitoring Data

(Part 1 in JGR-Oceans, October 2013 issue)

Aaron Bever, **Carl Friedrichs**, Marjy Friedrichs,

OUTLINE / SUMMARY

1. Use 3D models to examine uncertainties in interpolating Bay hypoxic volume.
   - Observed DO have coarse spatial resolution = spatial error
   - Observed DO are not a "snapshot" = temporal error
   - Use 3D models to improve EPA-CBP interpolations of hypoxic volume
2. Use "Geometric" method to estimate Bay hypoxic volume using 2 to 3 stations.
   - Compare EPA "Interpolated HV" (13 sites) to "Geometric HV"
   - Compare modeled "3D HV" (integrated 1000s of points) to "Geometric HV"

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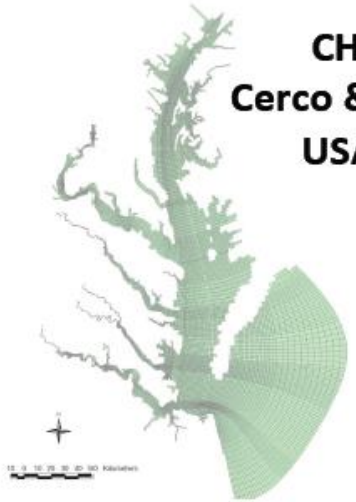
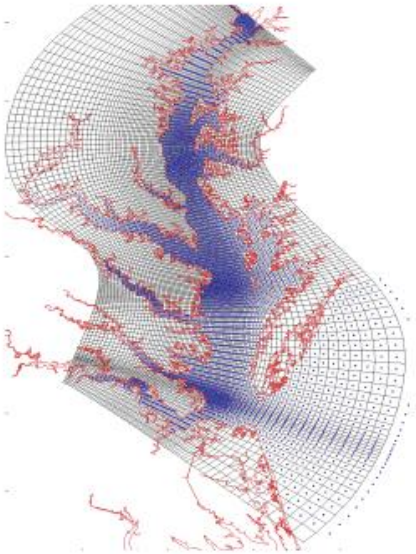
Five hydrodynamic models configured for the Bay



CH3D
Cerco & Wang
USACE

UMCES-ROMS
Li & Li
UMCES



EFDC
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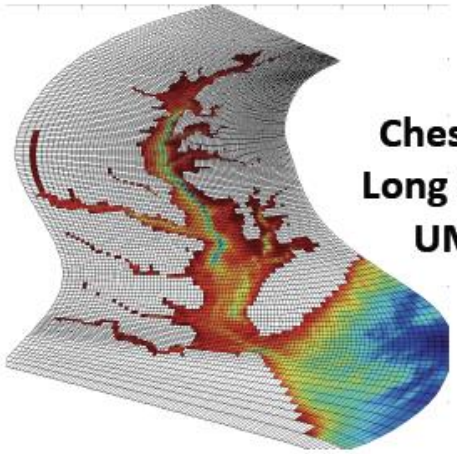
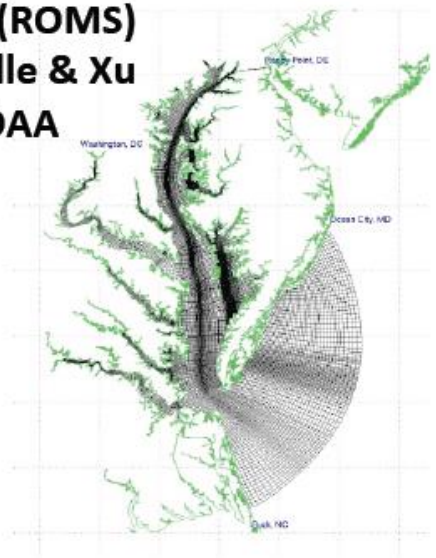


ChesROMS
Long & Hood
UMCES

CBOFS (ROMS)
Lanerolle & Xu
NOAA



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TODAY'S TALK

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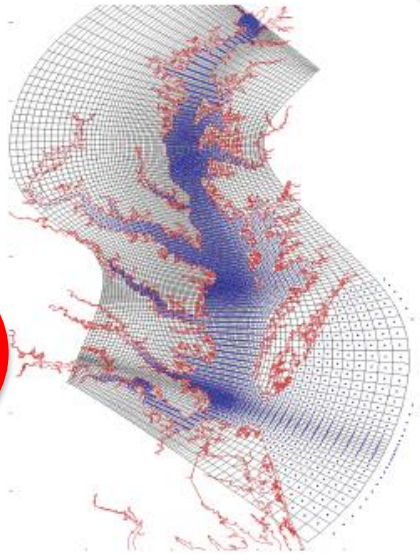

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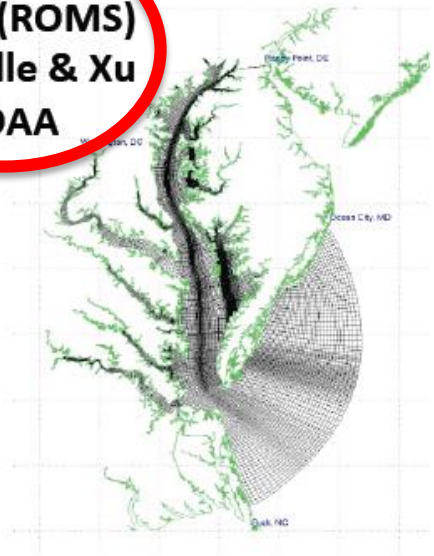

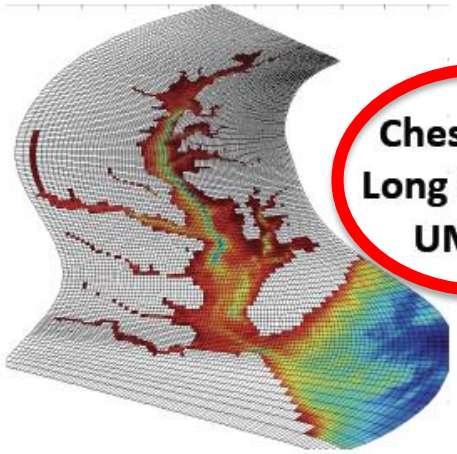

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Five dissolved oxygen (DO) models configured for the Bay

- **ICM**: EPA-CBP model; complex biology
- **BGC**: 3 NPZD-type biogeochemical models
- **1eqn**: Simple one equation respiration (includes SOD)
- **1term-DD**: depth-dependent respiration (not a function of x, y, temperature, nutrients…)
- **1term**: Constant net respiration (not a function of x, y, temperature, nutrients OR depth…)

Five dissolved oxygen (DO) models configured for the Bay

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TODAY'S TALK

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Five dissolved oxygen (DO) models configured for the Bay

Today's talk = Four combinations:

- CH3D + ICM ← **EPA-CBP model**
- CBOFS + 1term
- ChesROMS + 1term
- ChesROMS + 1term+DD

-- Physical models are similar, but grid resolution differs
-- Biological/DO models differ dramatically
-- All models run for 2004 and 2005 and compared to EPA Chesapeake Bay Program DO observations

Four Types of Hypoxic Volume Estimates

Interpolation Method used for #1 - #3:

- CBP Interpolator Tool
- HV = DO < 2 mg/L

#1) Observations

- Of 99 CBP stations (red dots), 30-65 are sampled each “cruise”
  Each cruise takes 1 to 2 weeks

#2) Modeled Absolute Match:

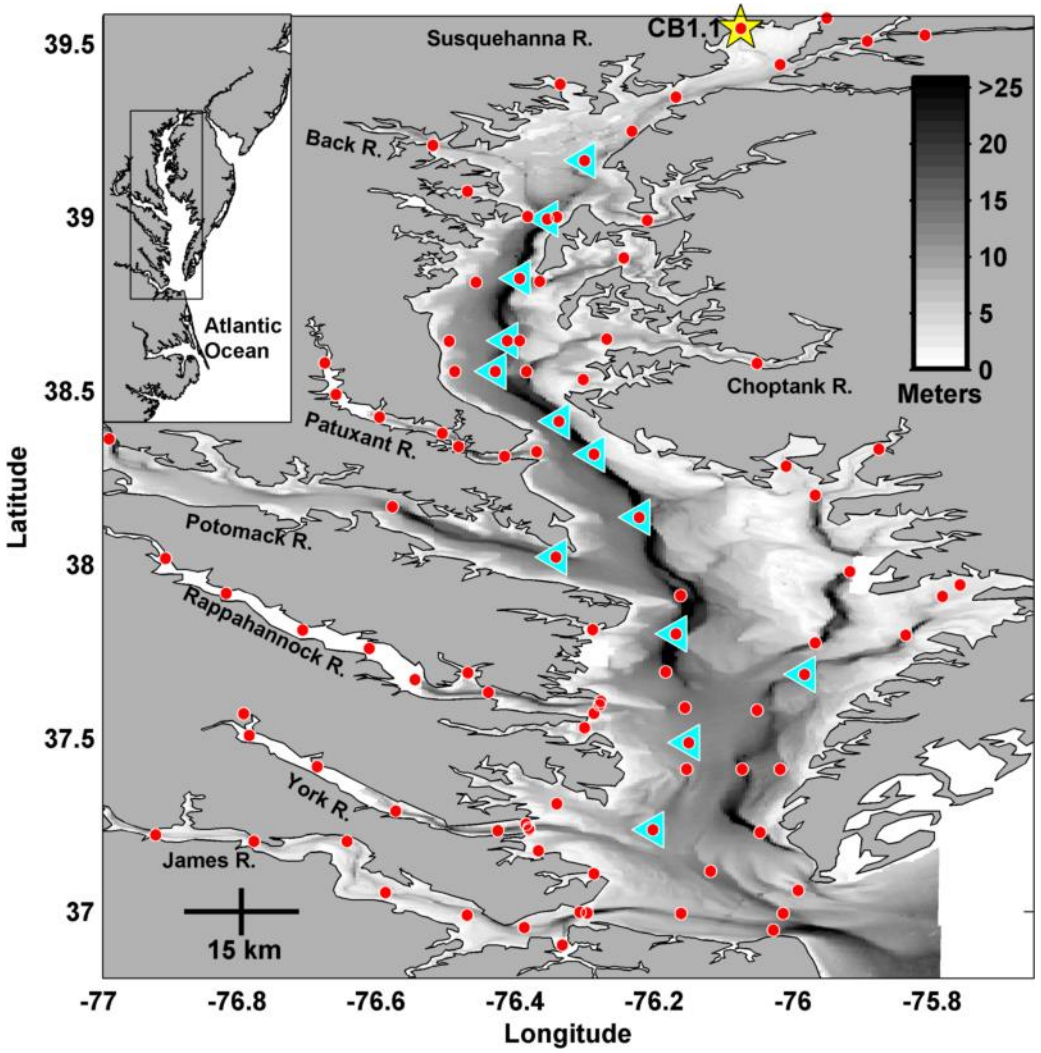
- Same 30-65 stations are “sampled” at same time/place as observations are available

#3) Modeled Spatial Match:

- Same stations are “sampled” in space, but samples are taken synoptically (i.e., all at once in time)

#4) Integrated 3D Model:

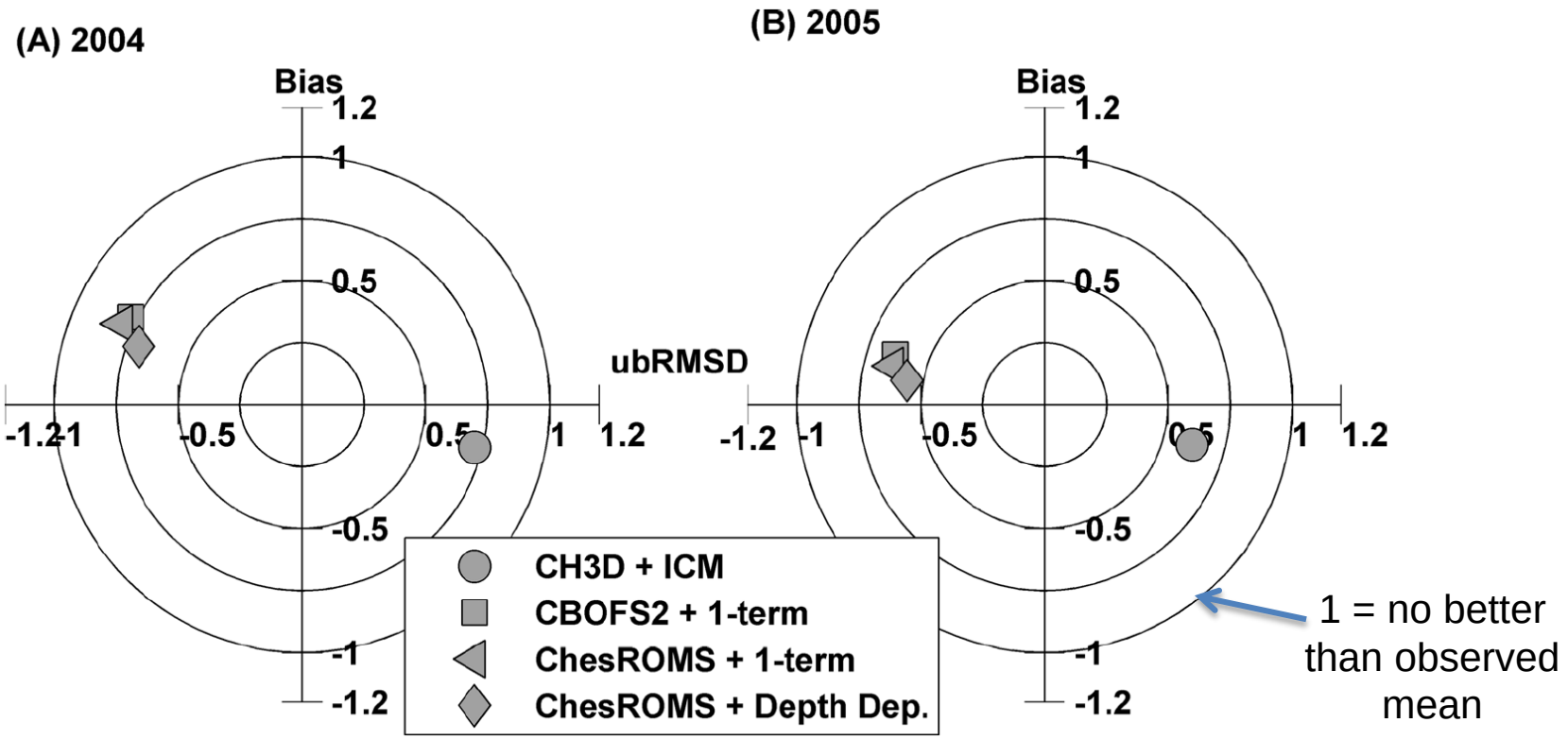
- Hypoxic volume is computed from integrating over all model grid cells



(“CBP” = EPA Chesapeake Bay Program)

Model skill: Bottom DO

Total $RMSD^2$ = $Bias^2$ + unbiased $RMSD^2$



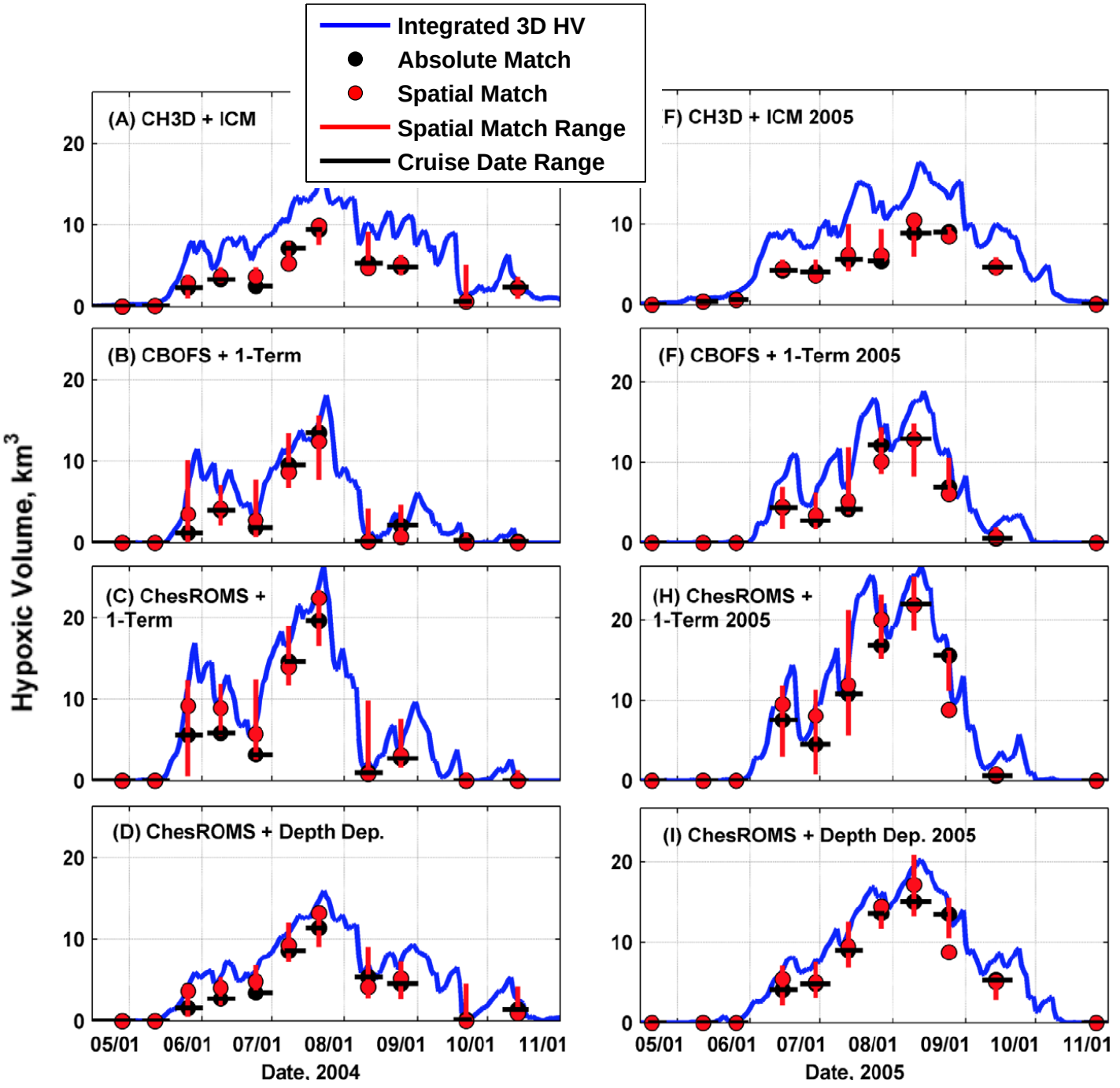
-- The models all have significant skill (normalized RSMD < 1) in reproducing observed bottom dissolved oxygen (DO).

-- The four models all reproduce observations of bottom DO about equally well.

-- Unlike observations, model output is continuous in space and time.

-- So use the continuous model output to estimate uncertainties caused by CBP interpolations of discontinous observed data.

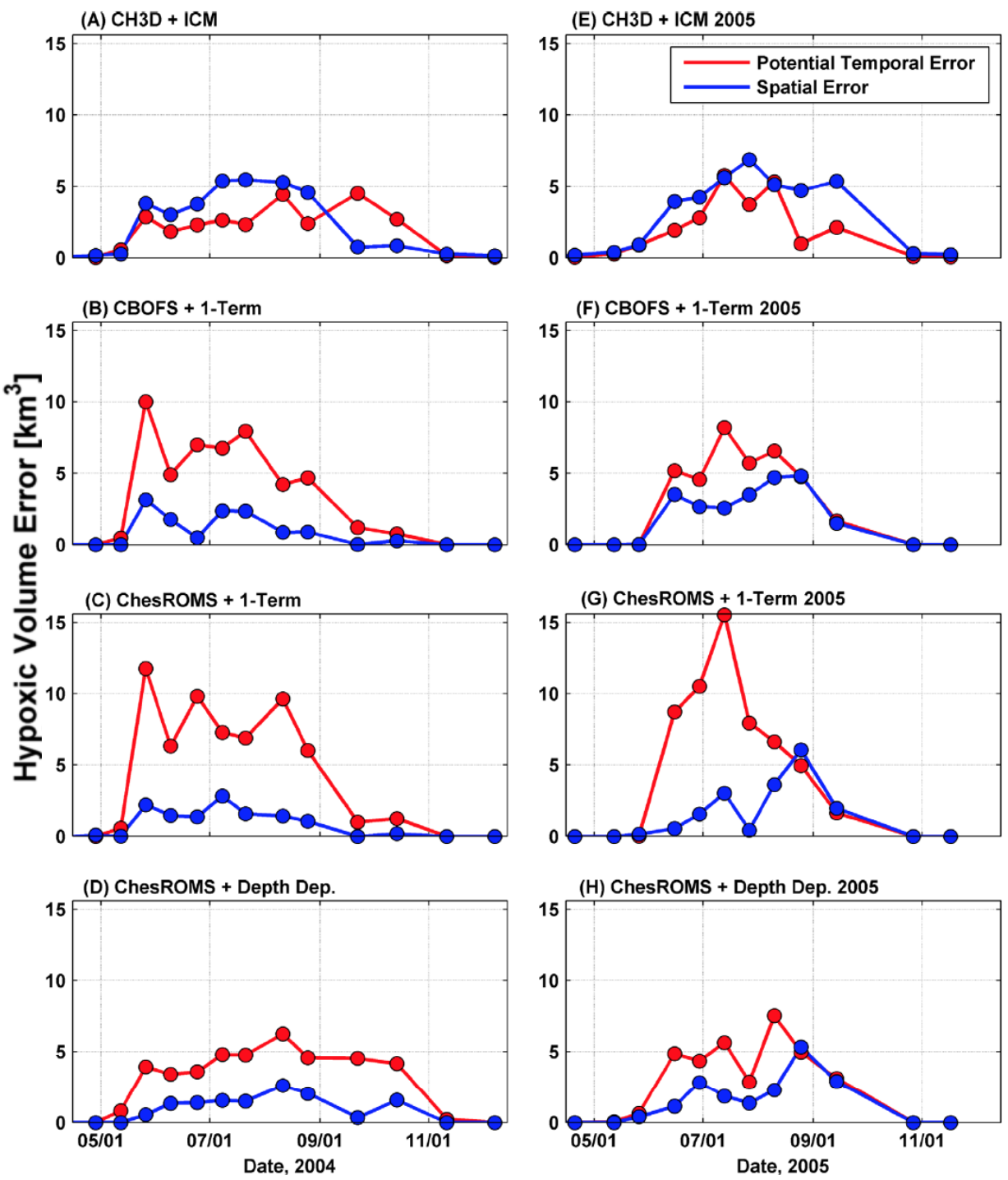
- Interpolated HV underestimates actual HV for every cruise
- Much of this disparity could be due to temporal errors (red bars)
- Spatial error is blue line minus red dots
- Same pattern across all 4 models for both 2004 & 2005



Spatial errors show interpolated HV is almost always too low (up to 5 km^3)

The temporal errors from non-synoptic sampling can be as large as spatial errors (~5 km^3)

Similar patterns across all 4 models for both 2004 & 2005

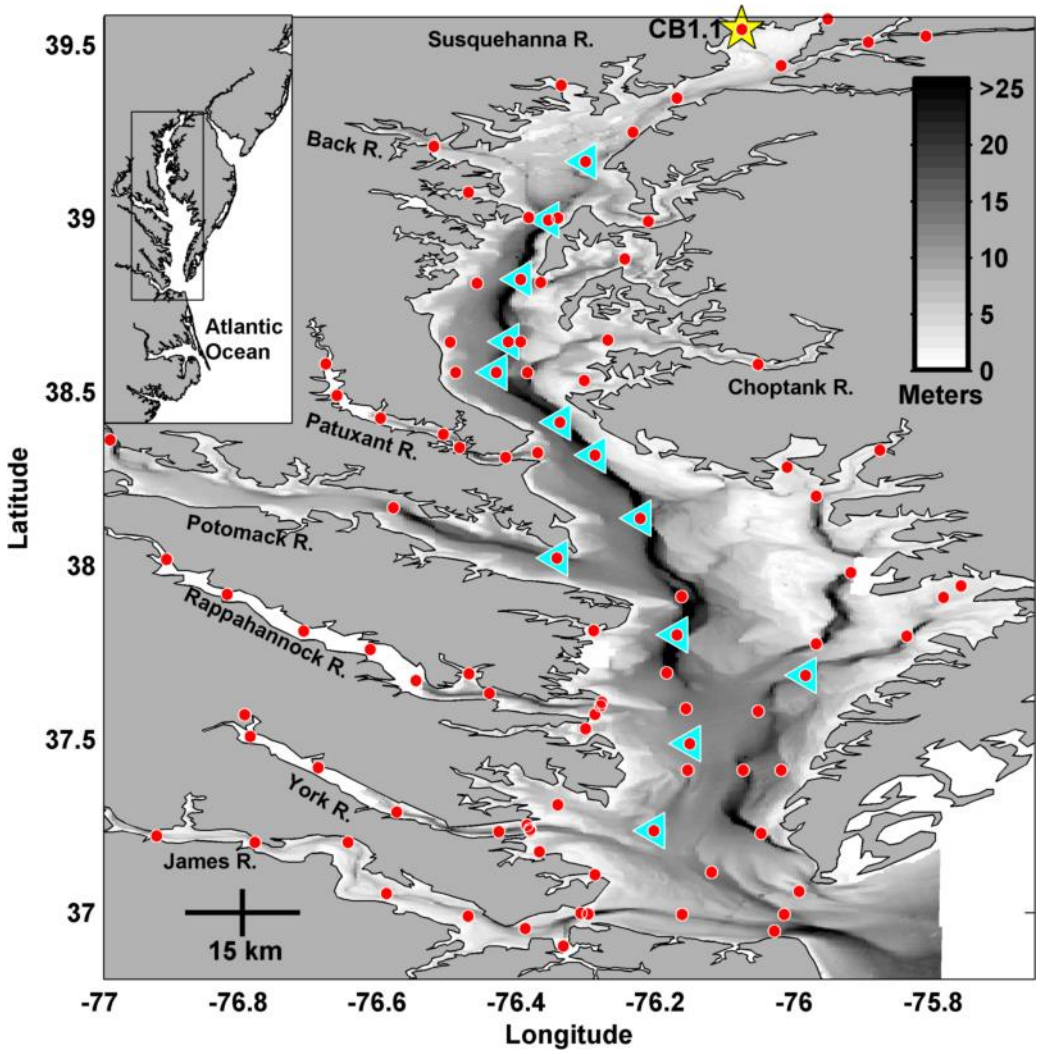


Improving observation-derived hypoxic volumes

- **Reduce <u>Temporal</u> errors:**

  1. Choose subset of 13 CBP stations
  2. Routinely sampled within 2.3 days of each other
  3. Characterized by high DO variability

Blue triangles = 13 selected CBP stations



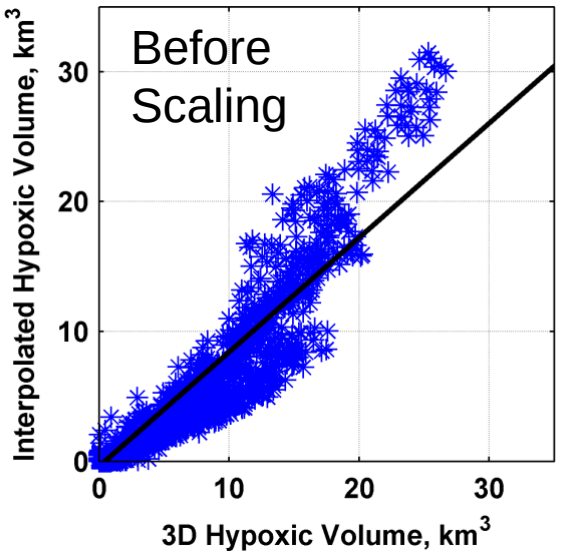
Improving observation-derived hypoxic volumes

- **Reduce <u>Spatial</u> errors:**

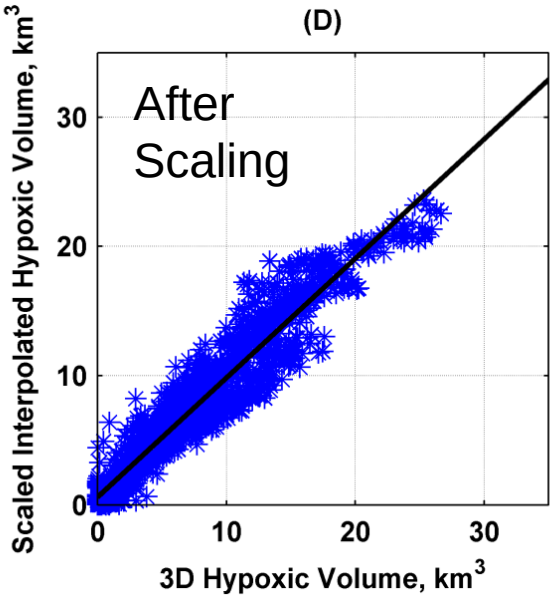
  1. For each model and each cruise, derive a correction factor as a function of interpolated HV that "corrects" this 13-station Spatial Match HV to equal the Integrated 3D HV.

  2. Apply correction factor to HV time-series

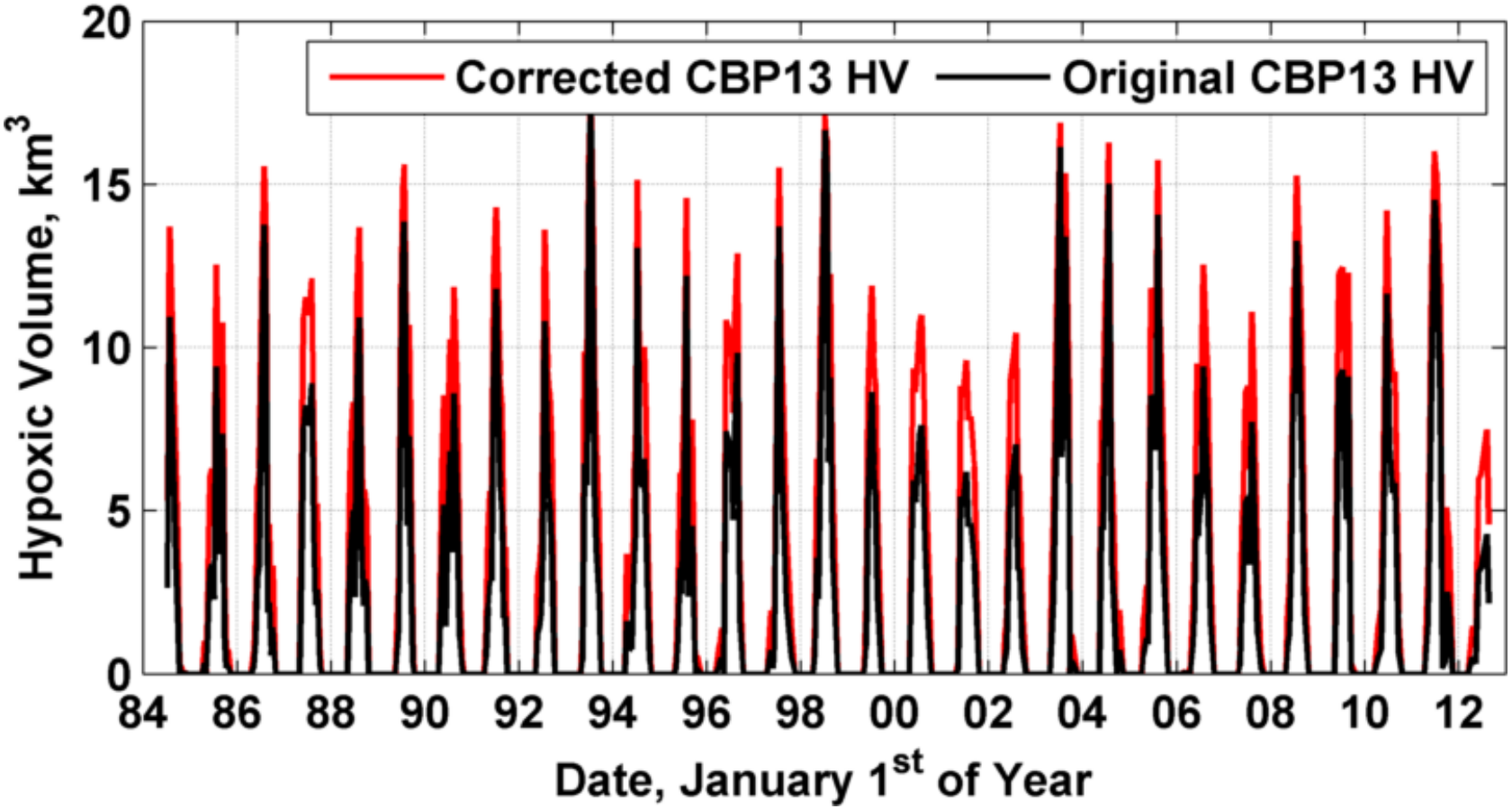
  3. Scaling-corrected "interpolated" HV more accurately represents true HV



(D)



Interannual (1984-2012) corrected (i.e., scaled) time series of observed Hypoxic Volume



- Time-series of corrected hypoxic volume for 1984-2012 are provided within JGR article (annual maximum HV, annual duration of HV, annual cumulative HV), and corrected HV for every CBP cruise is provided in JGR electronic supplement.

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- **Hypothesis:**

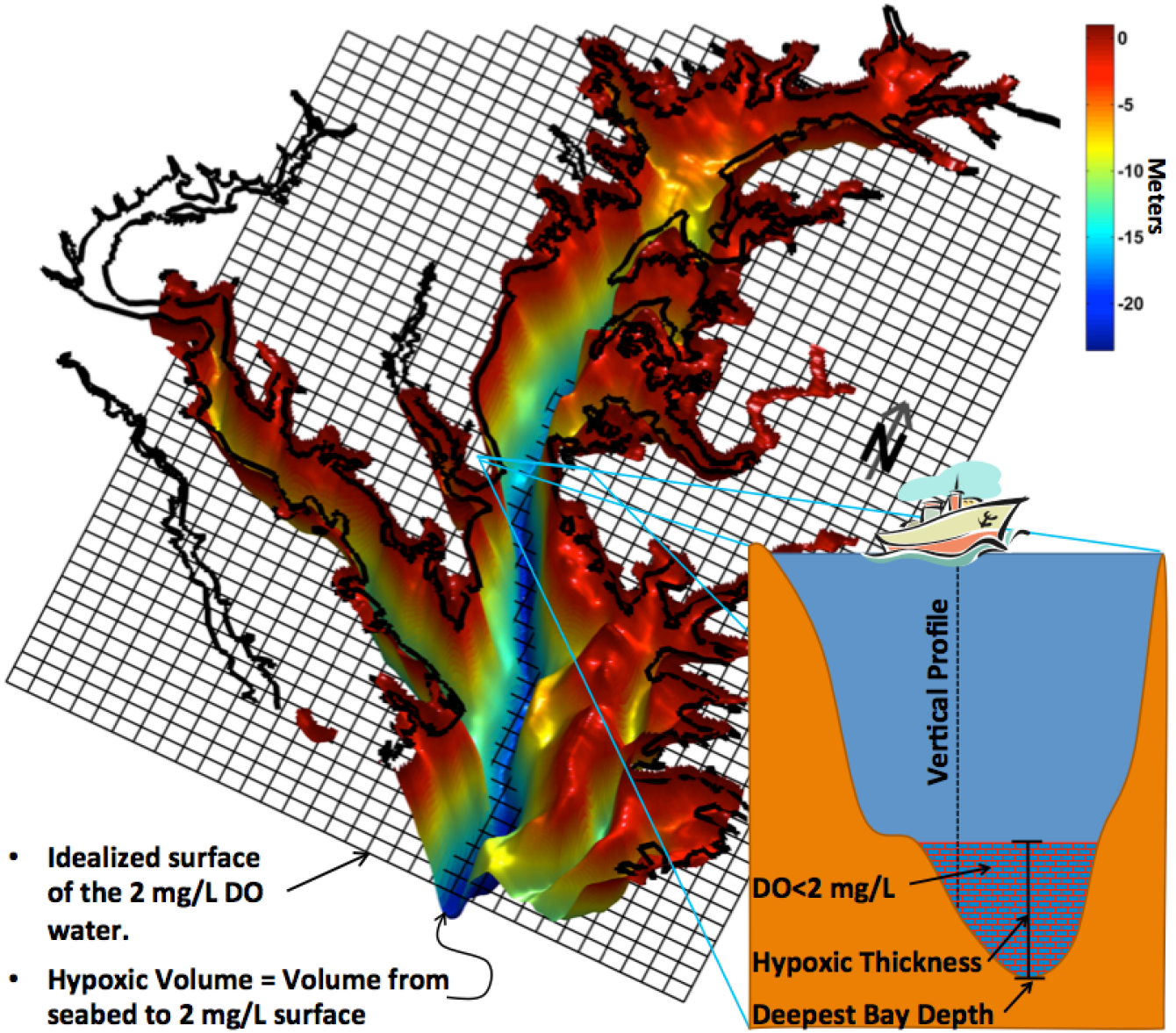
  For a given thickness of the hypoxic layer in the Chesapeake Bay, the horizontal extent of hypoxia is constrained by the steep topography of the Bay's deep channel.

  Therefore, the volume of hypoxic water can be reasonably estimated with data from a relatively small number of vertical profiles.

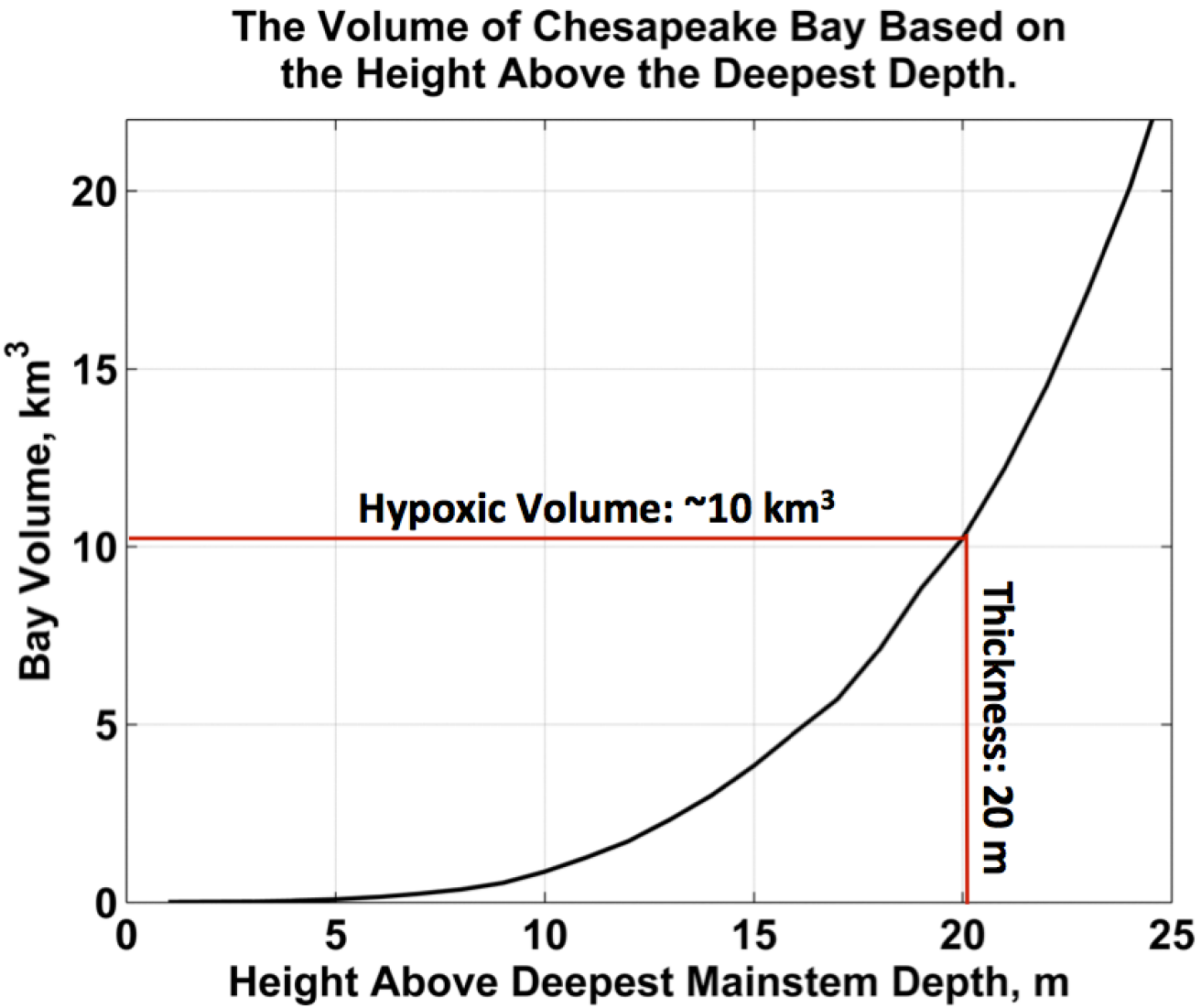
  If a few automated profilers or well-instrumented moorings can report oxygen data in real time, then the hypoxic volume (HV) of the Bay can be reasonably estimated in real time.

➢ Methods:

Compare "Geometric HV" calculations to (1) "Interpolated HV" estimates from EPA monitoring and (2) "Integrated 3D HV" from 3D modeling.

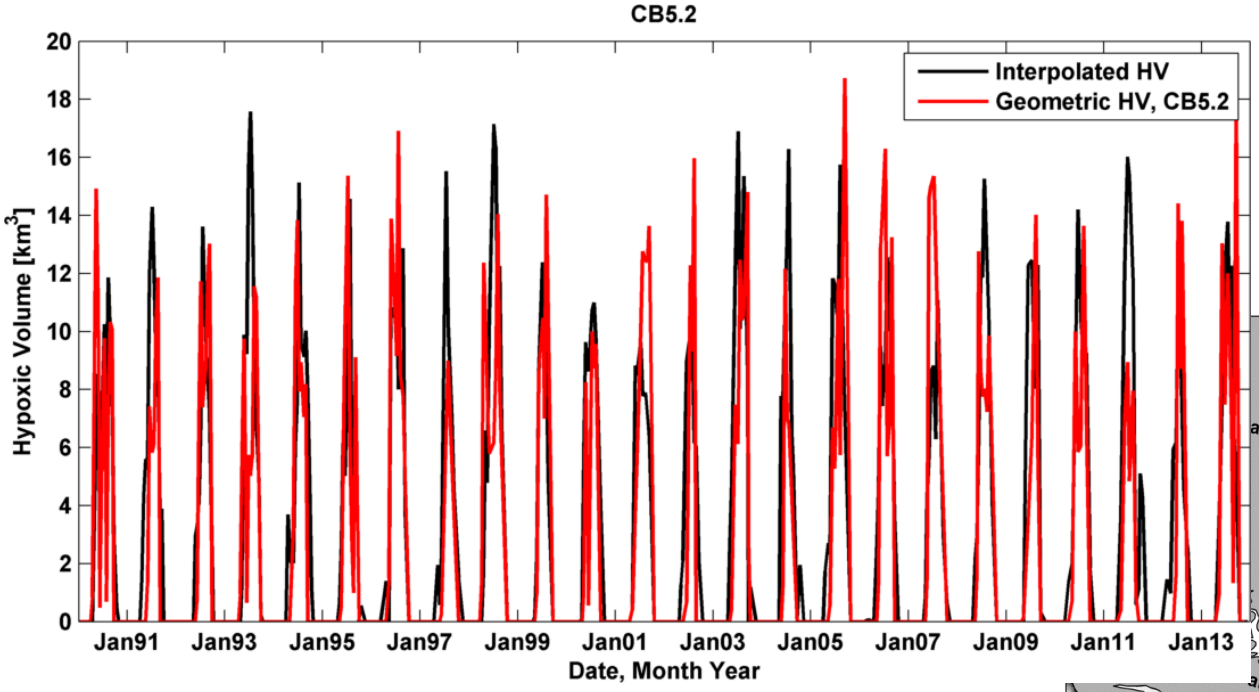


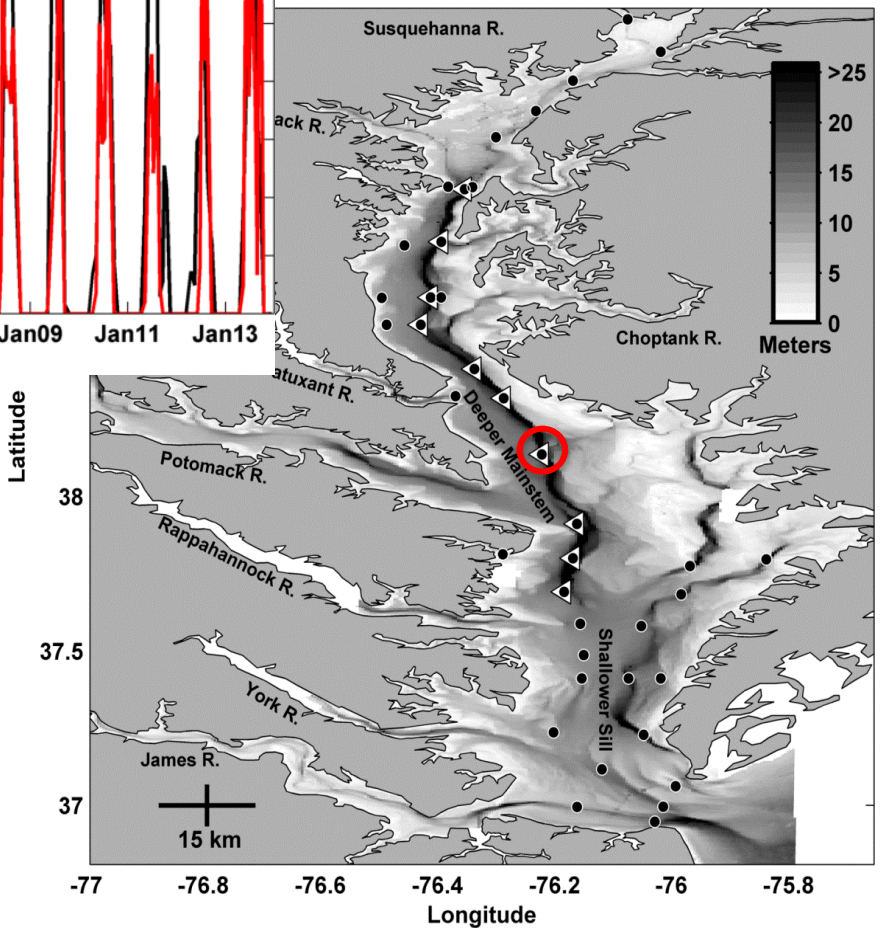
➢ Methods (cont.):



➢ Results (1): Monitoring Cruise Data (every 2 to 4 weeks for 28 years)

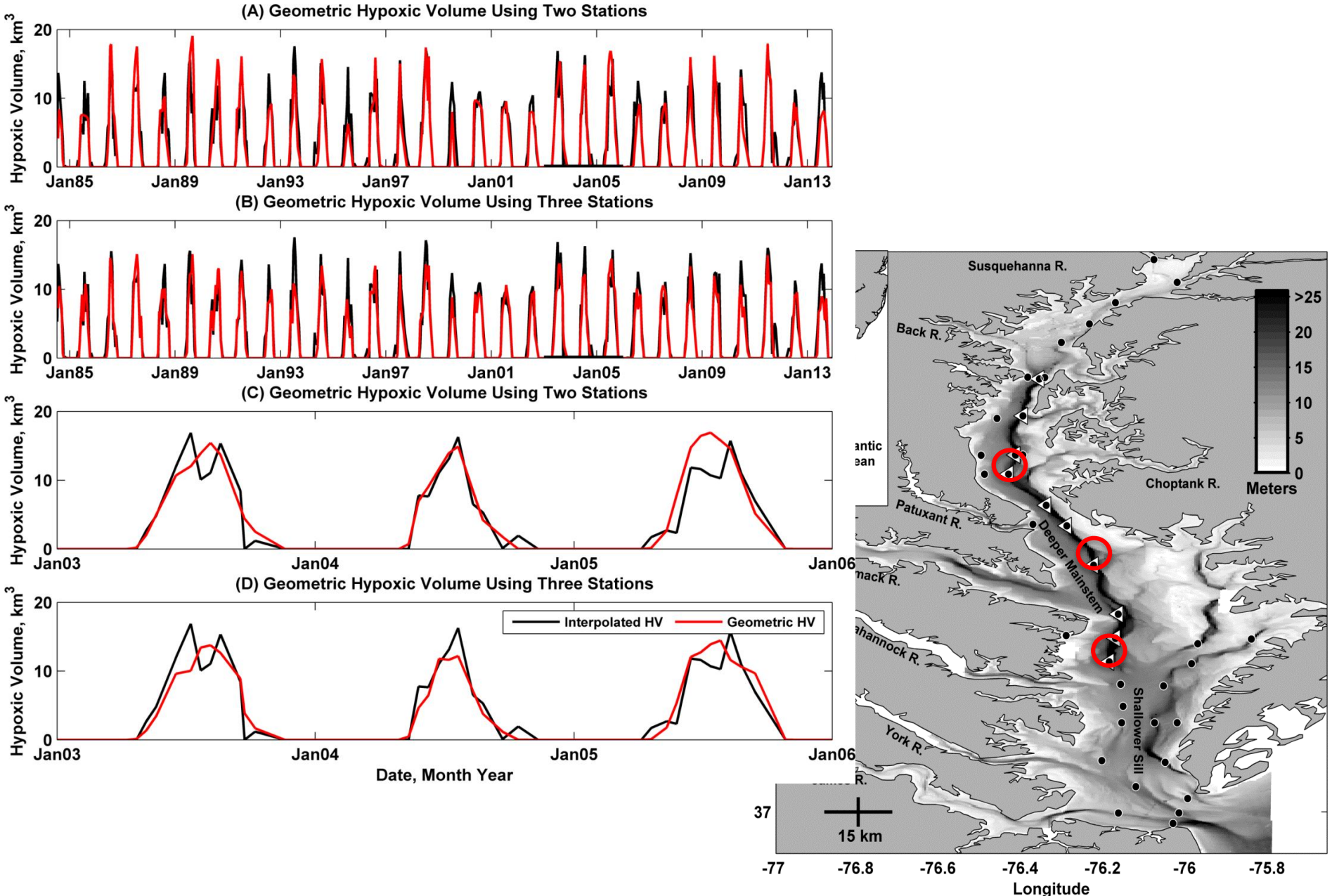
Compare “Interpolated HV” (13 sites) to “Geometric HV” with **1 site**:





➢ Results (1): Monitoring Cruise Data (every 2 to 4 weeks for 28 years)

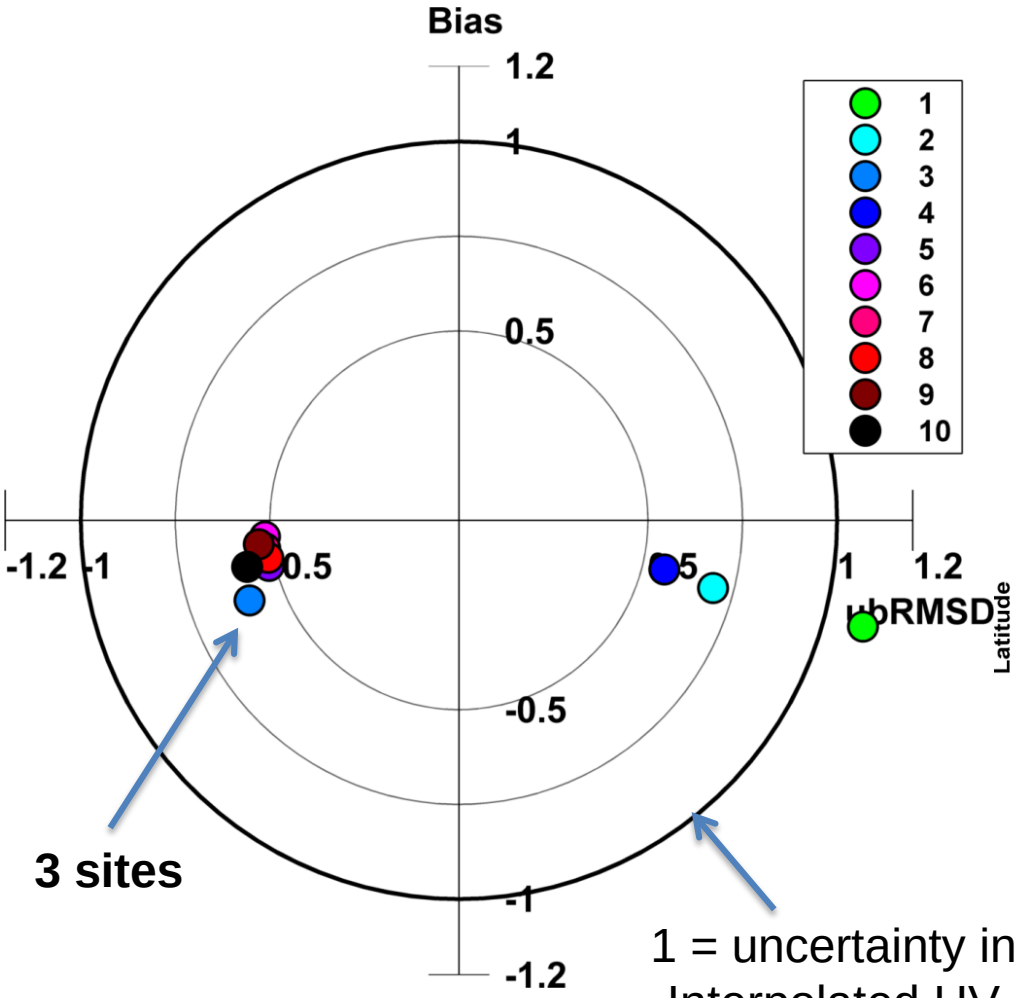
Compare “Interpolated HV” (13 sites) to “Geometric HV” with **2 to 3 sites**:

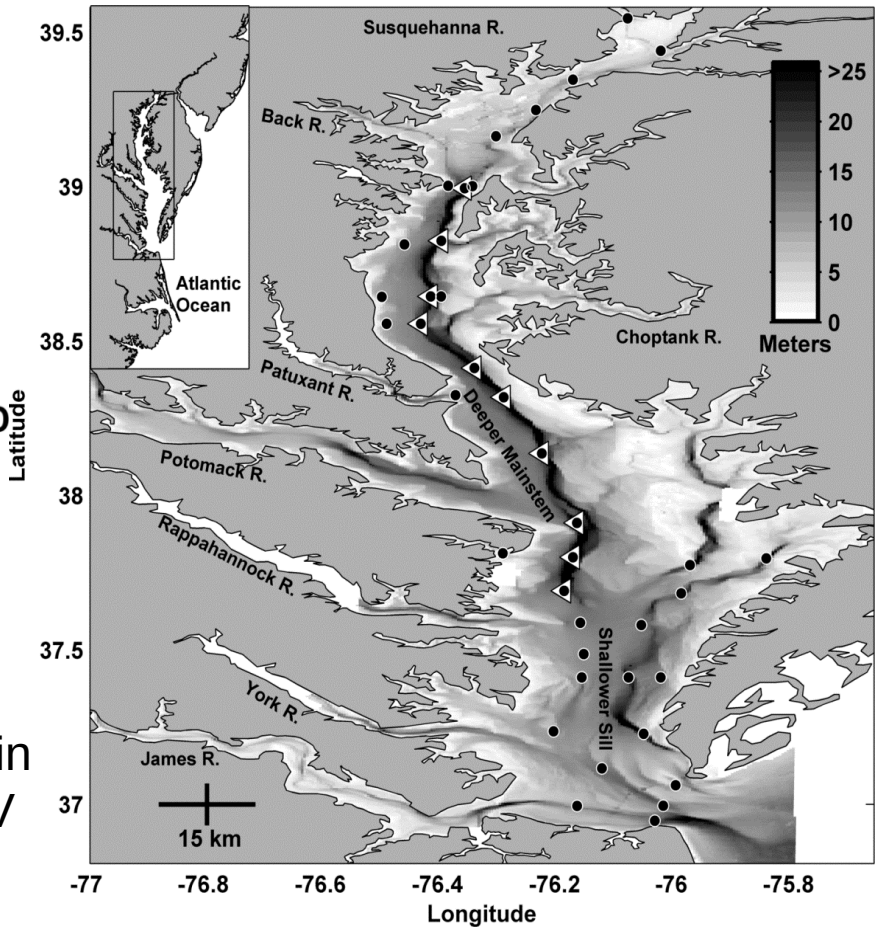


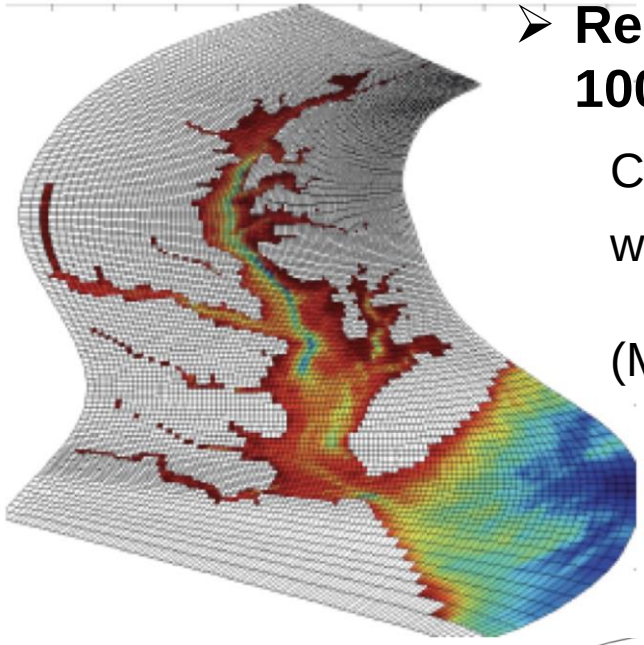
➢ Results (1): Monitoring Cruise Data (every 2 to 4 weeks for 28 years)

Compare “Interpolated HV” (13 sites) to “Geometric HV” with **1 to 10 sites**.

Target diagram indicates that **3 sites** for “Geometric HV” are nearly as good as 10.



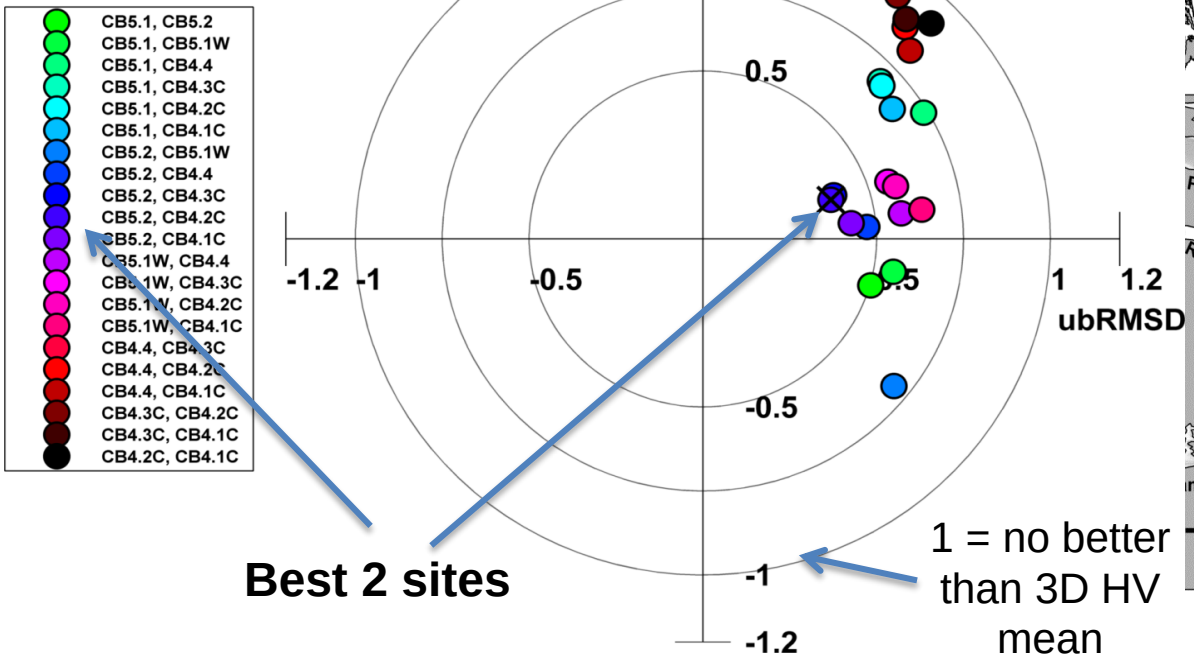




➢ Results (2): 3D Model Output (Integrated over 1000s of grid points daily for 20 years)

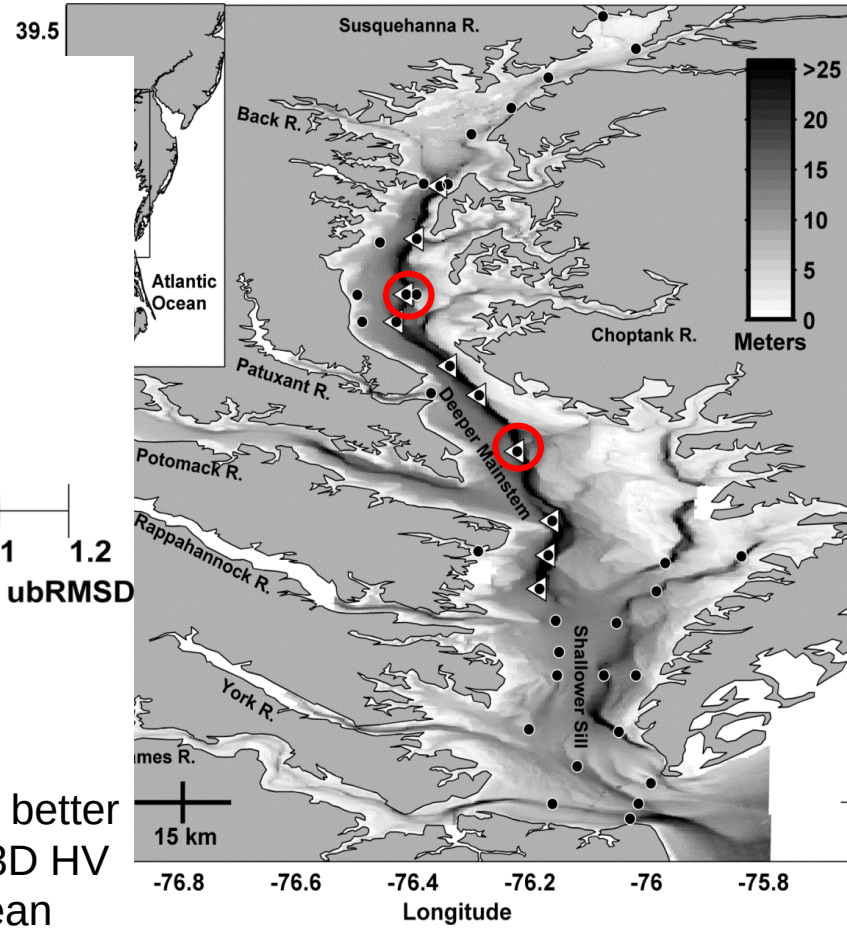
Compare “3D HV” (1000s of points) to “Geometric HV” with **2 sites**:

(Model = ChesROMS + 1-term constant net respiration)



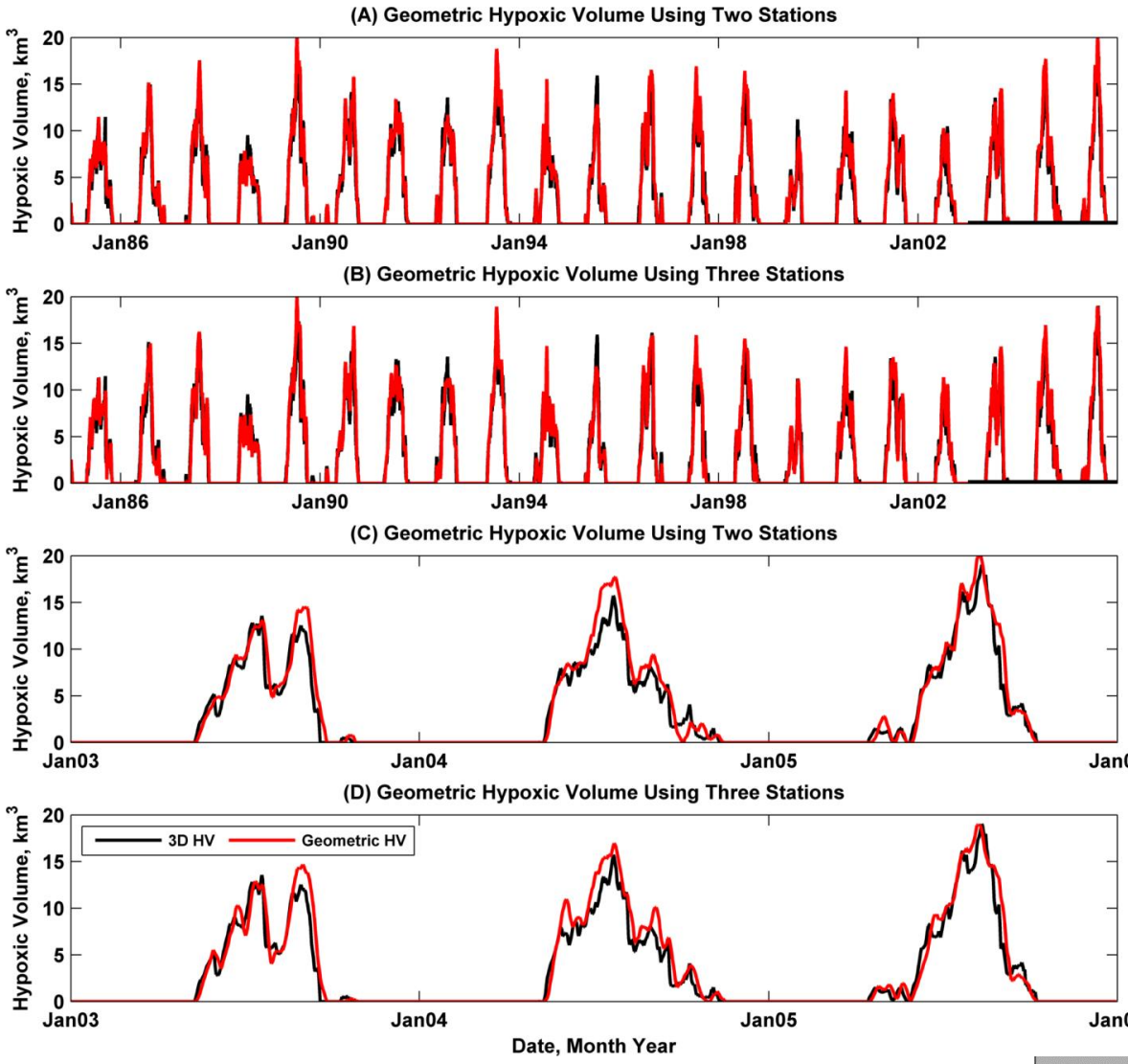
Best 2 sites

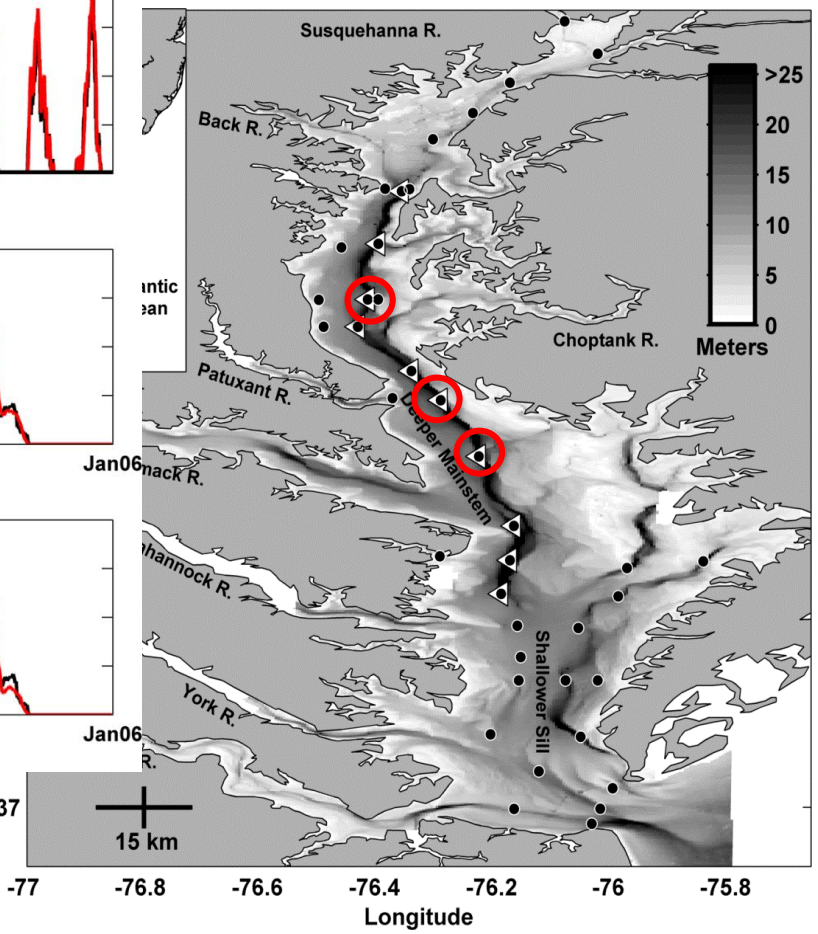
1 = no better than 3D HV mean



➢ Results (2): 3D Model Output (1000s of grid points daily for 20 years)

Compare "3D HV" (1000s of points) to "Geometric HV" with with **2 to 3 sites**:





For 3D model output, **2 sites** for "Geometric HV" are as good as 3.

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Summary/Conclusions

- **Information from multiple models (2004-2005) has been used to assess uncertainties in present CBP interpolated hypoxic volume estimates**
  - Temporal and spatial uncertainties: up to ~5 km^3

  → These are significant, given maximum HV is ~10-15 km^3

- **A method for correcting interpolated HV time series for temporal and spatial errors has been presented, based on the 3D structure of multiple model DO results**
  - 13 stations (sample in 2 days) do as well for HV as 40-60 or more

- **Info from 20+ years based on monitoring and simplest 3D model output suggests that 2 to 3 well-chosen stations can do almost as well as 13**
  - 2 to 3 automated stations could also provide continuous real-time HV

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