The Wind Effect on Chesapeake Bay Destratification and Hypoxia

Ping Wang, Harry Wang, Lewis Linker & Richard Tian

Chesapeake Bay Program
Modeling Quarterly Meeting
April 10, 2013
Introduction

• The effect of wind on circulation and Chesapeake Bay anoxia has been recognized by several researchers, however, different opinions exist on the extents of wind’s effect: e.g., the inter-annual variability of hypoxia is mainly controlled by wind or by nutrient loads.

* How do the observed data and the simulations by the Chesapeake Bay regulatory model, i.e., the coupled CH3D_hydrodynamic & ICM_WQSTM, indicate the wind effect on hypoxia?
Findings

• Wind can significantly erode destratification and hypoxia.
• Under a specific wind speed, destratification and hypoxia reduction are different by different wind directions. Longitudinal and cross-channel speeds, and channel bathymetry play significant roles.
• The extents of eroding stratification and hypoxia by different wind directions differ, however, strengths of wind, i.e., speed, is more important.
• The inter-annual variability of hypoxia is mainly controlled by nutrient load, while episodic winds cause hypoxia variation in different sampling cruises or months in a summer.
Scully, 2010

CH3D: 8 m/s, 2 Days.

ROMS: 6 m/s, 3 Days.
Susquehanna R.

Patuxent R.

Choptank R.

P8: center channel profile

Bay Mouth, to Atlantic Ocean
Cell Locations Along the Channel

- CB5.5
- CB5.4
- CB4.4
- CB4.3C
- CB4.2C
- CB4.1C
- CB5.1

DO (mg/l)

- S>N W>E
- N>S E>W
- S>N E>W
- W>E or E>W
- N>S E>W
- S>N

To the Bay mouth, south.

To the Bay head, north.
The direction of bottom current is mainly controlled by return flow from the bank besides the estuarine circulation, instead of the Ekman spiral. Therefore, channel bathymetry has significant effect on cross channel circulation.

Tidal averaged speed under wind at 8 m/s for 4 artificial directions.

1. Speed at surface
2. Speed at mid layer
3. Speed near bottom

~ 10 cm/s of speed
Bay Mouth, to Atlantic Ocean
DO mg/l

V, p4, N wind
V, p4, S wind
V, p4, E wind
V, p4, W wind

Speed at surface
Speed at mid layer
Speed near bottom

~ 10 cm/s of speed
Bay Mouth, to Atlantic Ocean
AV changes vs. no-wind

Anoxic Volume (km$^3$) vs. Days elapsed

August, 10

6.45 km$^3$ at no wind
Speed = 6 m/s, 2 days

Starts

Ends

AV changes vs. no-wind

August, 10

12.4 km$^3$ at no wind

Speed = 8 m/s, 2 days

Starts

Ends

AV changes vs. no-wind

August, 10

12.4 km$^3$

at no wind

Starts

Ends
Conclusions

• Wind can reduce stratification and summer anoxic volumes significantly. Direct wind mixing, and lateral circulation (associated with longitudinal and cross channel straining) are the main factors for destratification by winds.

• The shape or bathymetry of cross channel is another factor that plays an important role in causing differential influences on wind-induced circulation among wind directions.
Conclusions (cont.)

• In general, south and north winds reduce more anoxic volume than east and west winds; south wind affects the most (because of stronger longitudinal straining and wind direct mixing), while west wind the least.

• Although the extents of eroding stratification and hypoxia are different for different wind directions, the strengths of wind (i.e., speed) over certain threshold is more important. Longer duration of strong wind also has a stronger impact.
Conclusions (cont.)

- Watershed load is the key factor controlling inter-annual hypoxia ($r \approx 0.85$). While episodic strong wind can reduce hypoxia significantly, causing variations of hypoxia among months or different sampling cruises in a summer.
Thank you.