Recalcitrance and Tipping Points in Chesapeake Bay Hypoxia

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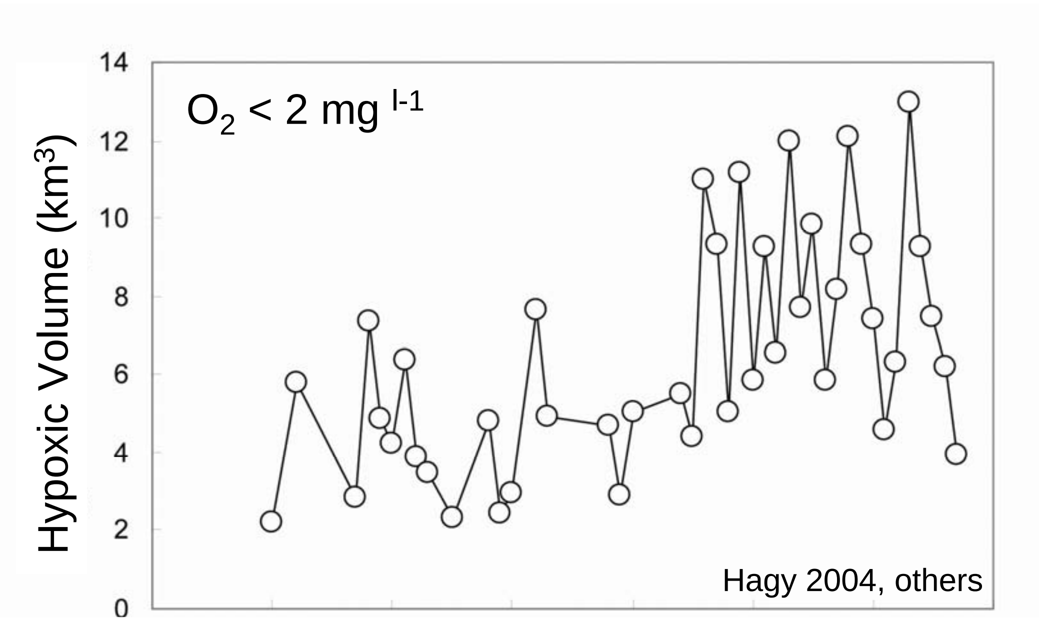
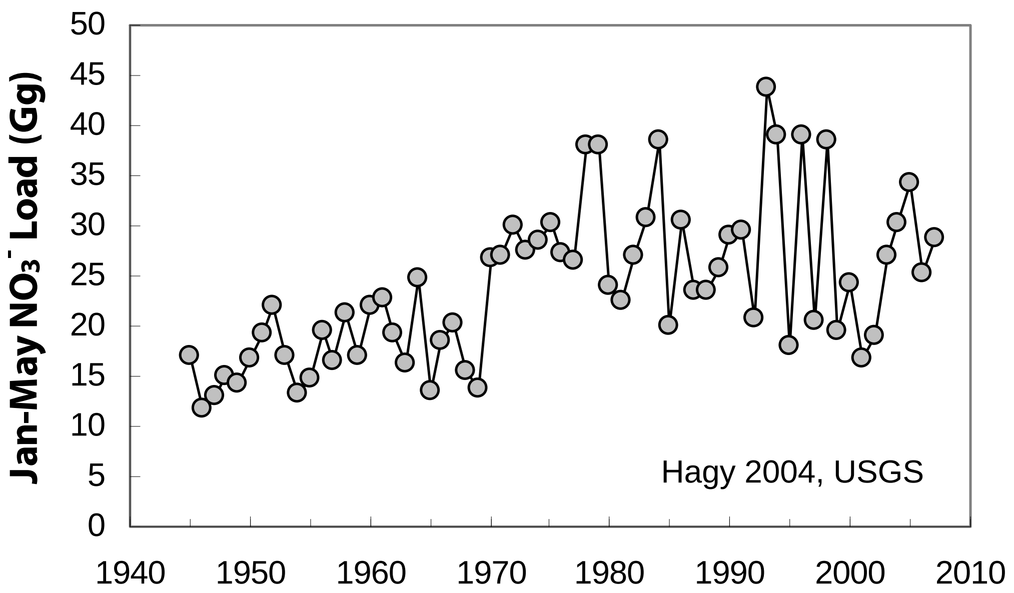
Outline

- **Chesapeake Bay Hypoxia Trends & Controls**
  - -Long-term hypoxic volume & nutrient trends
- **Hypoxia-Nutrient "Regime Shift" in Chesapeake Bay?**
  - -Response trajectories
  - -Possible explanation: Enhanced N-Recycling
- **Concluding Comments**
  - -Future work
  - -Other potential causes of increased hypoxia

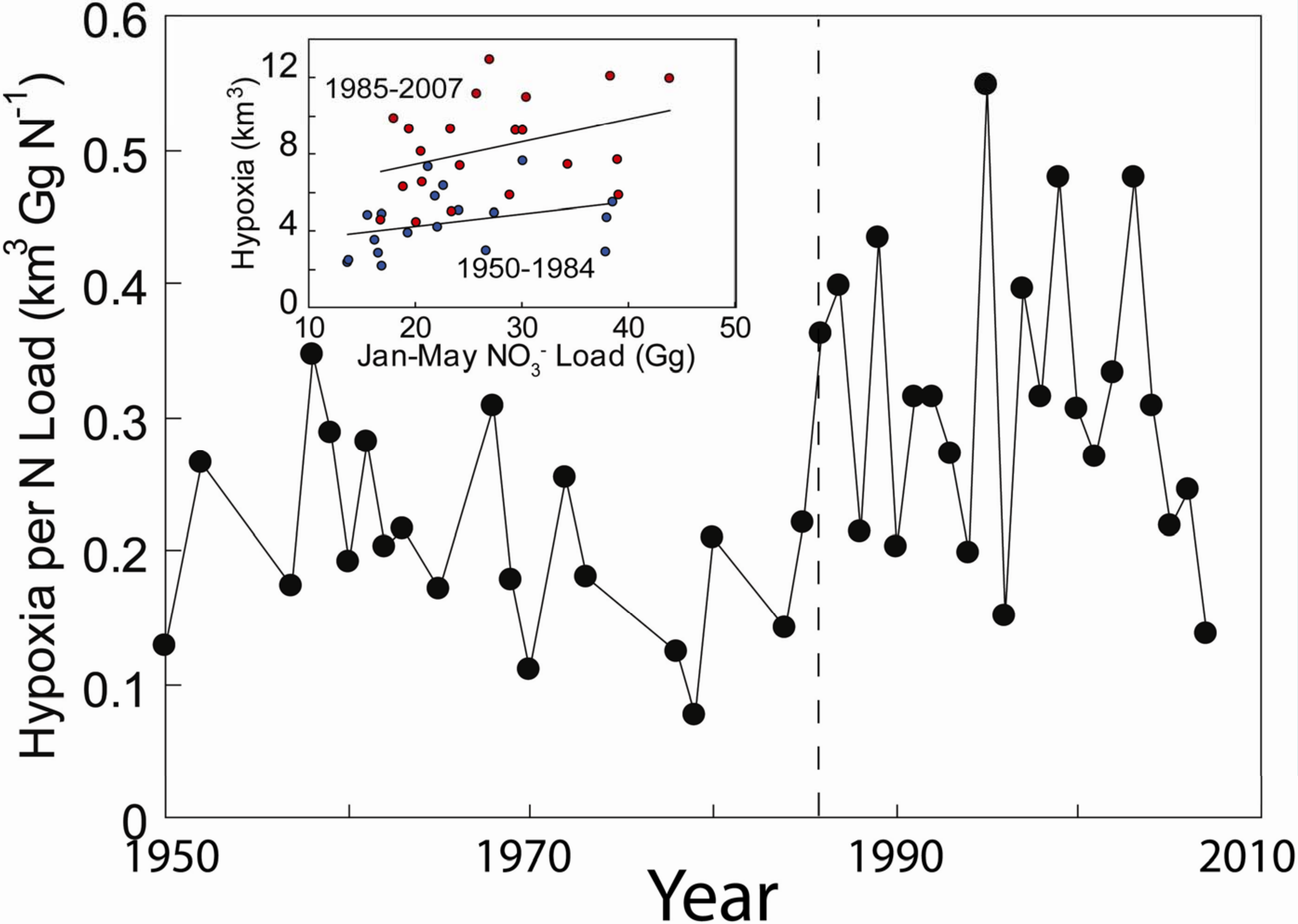
Increasing Trend in Bay Summer Hypoxia Volume (1950-2007)



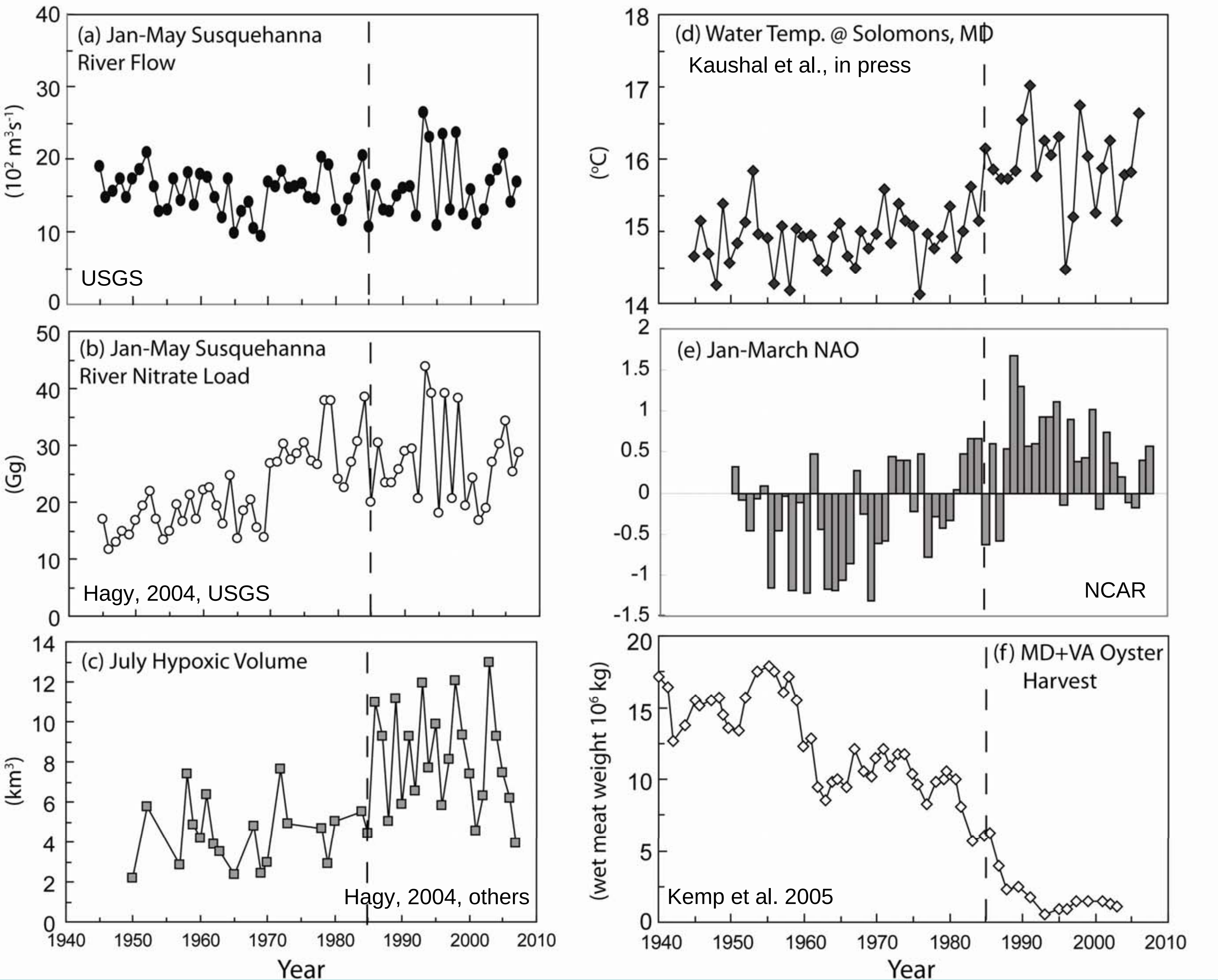
- **Long-term increase in Chesapeake hypoxia**



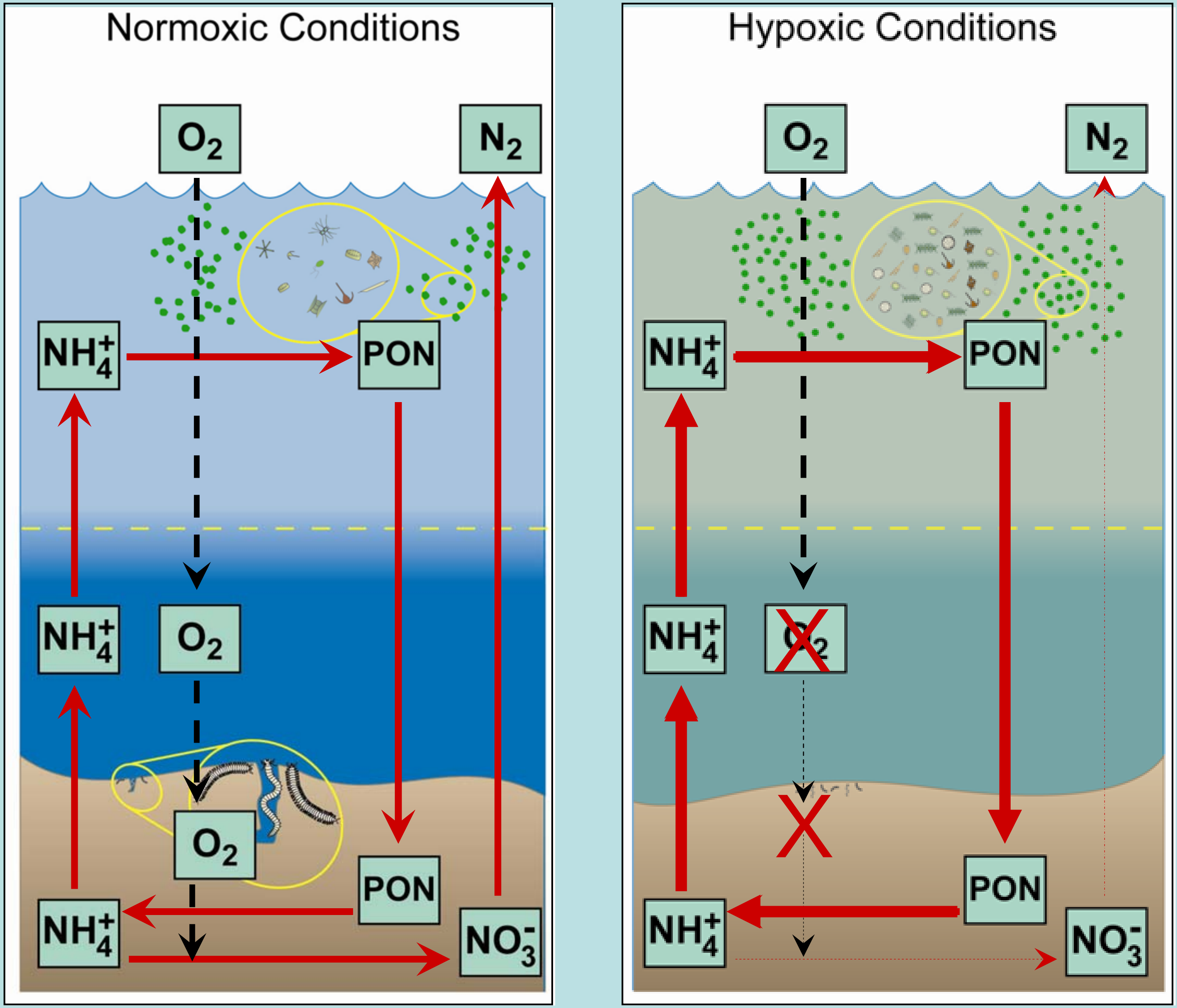
- **Increase in Chesapeake hypoxia linked to spring nitrate load**



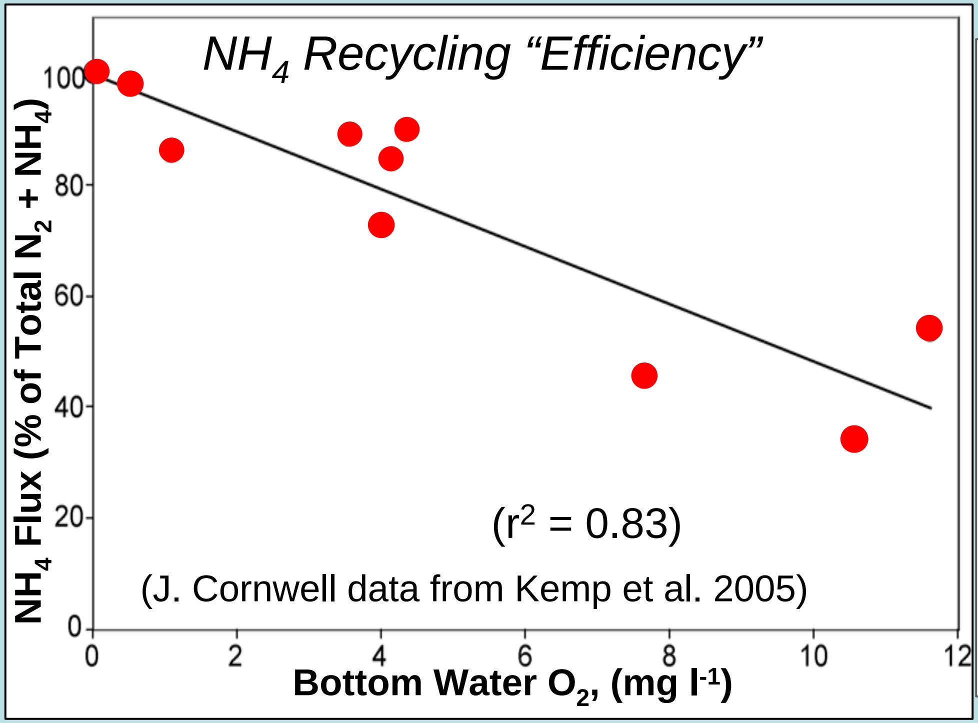
Hypoxia per N Load (km^3 Gg N^{-1})
0.6
0.5
0.4
0.3
0.2
0.1
0
1950
1970
1990
2010
Year
Hypoxia (km^3)
12
8
4
0
10
20
30
40
50
Jan-May NO_3^- Load (Gg)
1985-2007
1950-1984

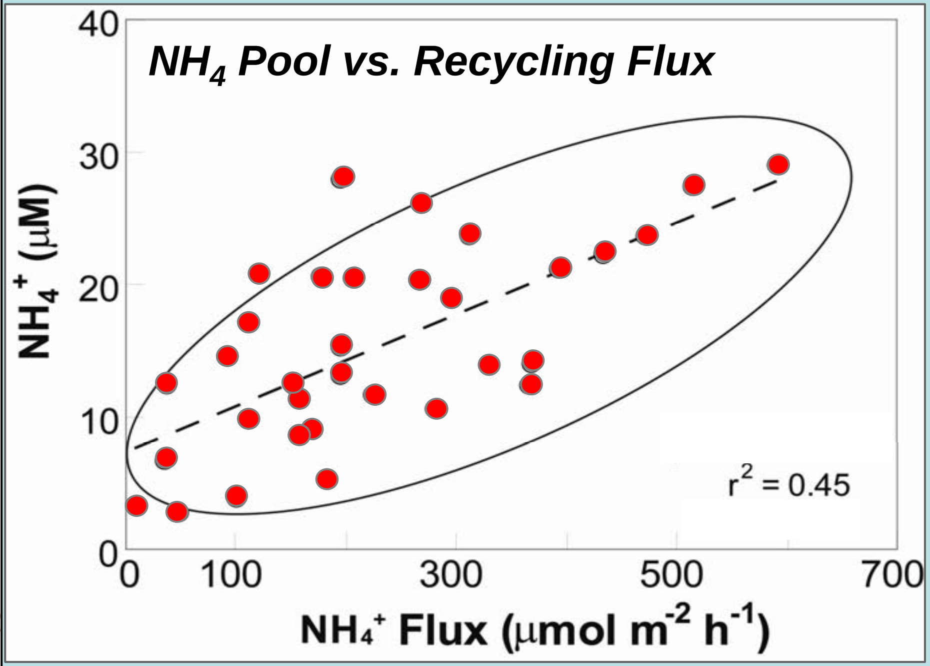

(a) Jan-May Susquehanna River Flow
USGS
(10² m³s⁻¹)
(b) Jan-May Susquehanna River Nitrate Load
Hagy, 2004, USGS
(Gg)
(c) July Hypoxic Volume
Hagy, 2004, others
(km³)
Year
(d) Water Temp. @ Solomons, MD
Kaushal et al., in press
(°C)
(e) Jan-March NAO
NCAR
(f) MD+VA Oyster Harvest
Kemp et al. 2005
(wet meat weight 10⁶ kg)
Year

Conceptual Model of O_2 Interactions with N-Cycle



Hypoxia Enhancement of Benthic Nutrient (NH_4^+) Recycling Efficiency



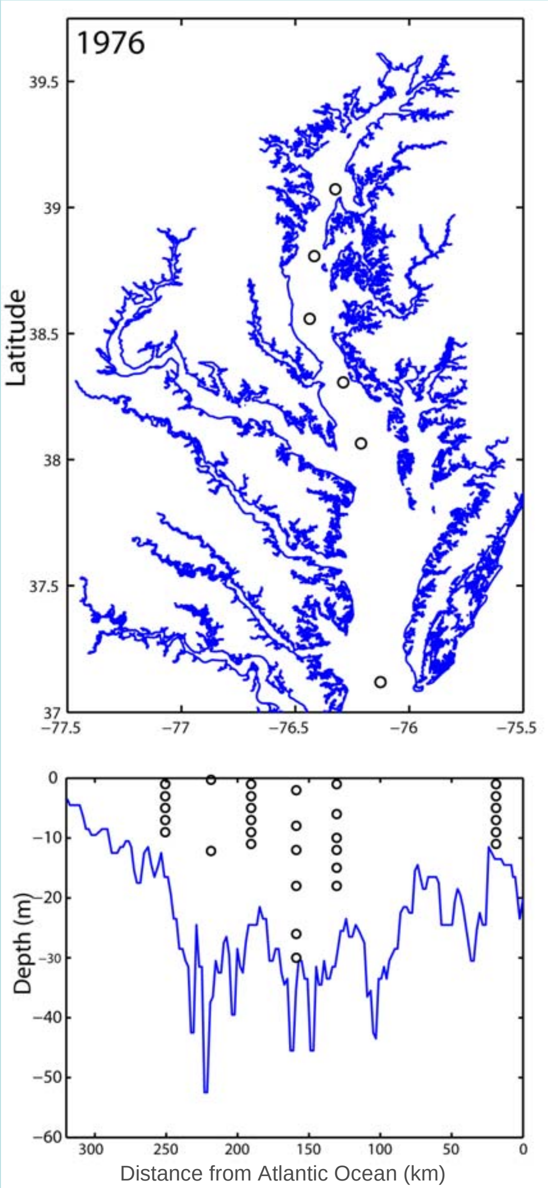


(Data from W. Boynton and E. Bailey)

- **DIN 'Recycling Efficiency' (NRE) is flux ratio (DIN/(DIN + N_2)**
- **NRE increases w/ decreasing O_2 because of nitrification inhibition**
- **Thus, DIN recycling higher under hypoxic conditions.**

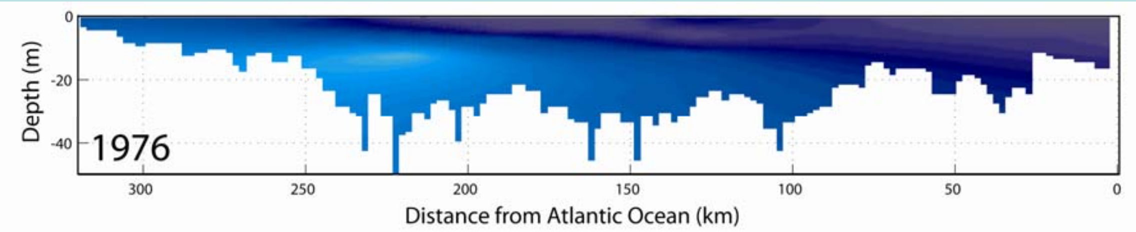
Computing NH_4^+-N Mass in Chesapeake Bay: Workflow

1) NH_4^+ Observations in summer

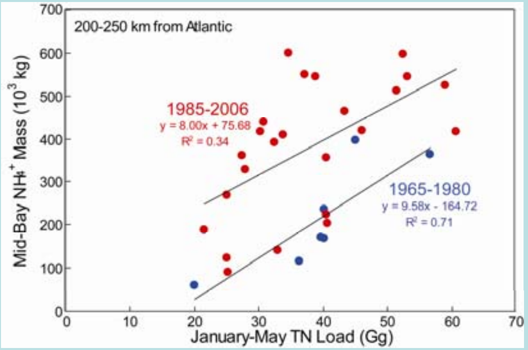


(Data: Maryland DNR, CBI)

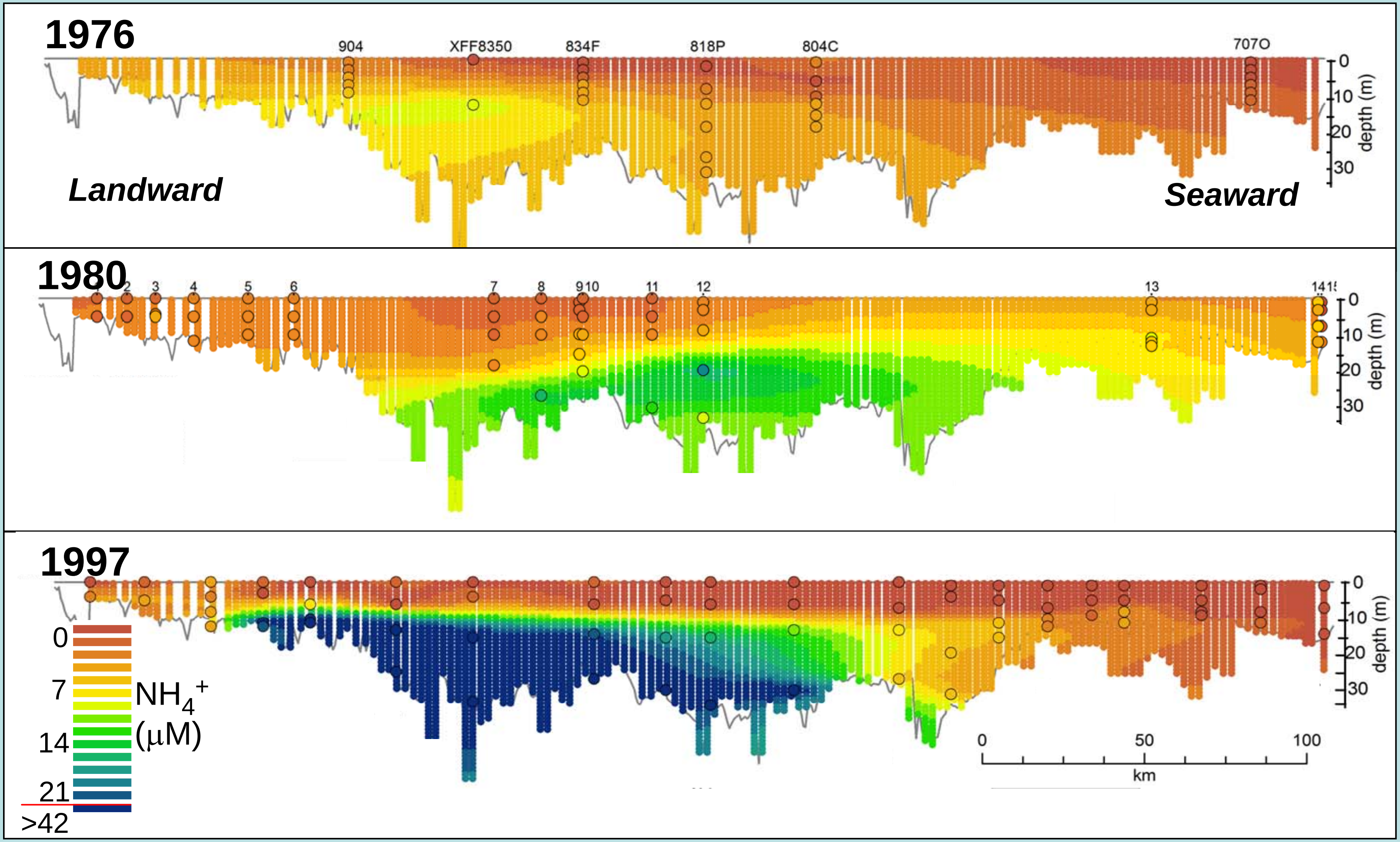
2) Interpolate NH_4^+ observations with 2D interpolation (kriging)



2) Compute NH_4^+-N Mass below pycnocline in several regions of Chesapeake Bay – compare these masses to TN loads



Decadal Change in July Distribution of [NH_4^+]

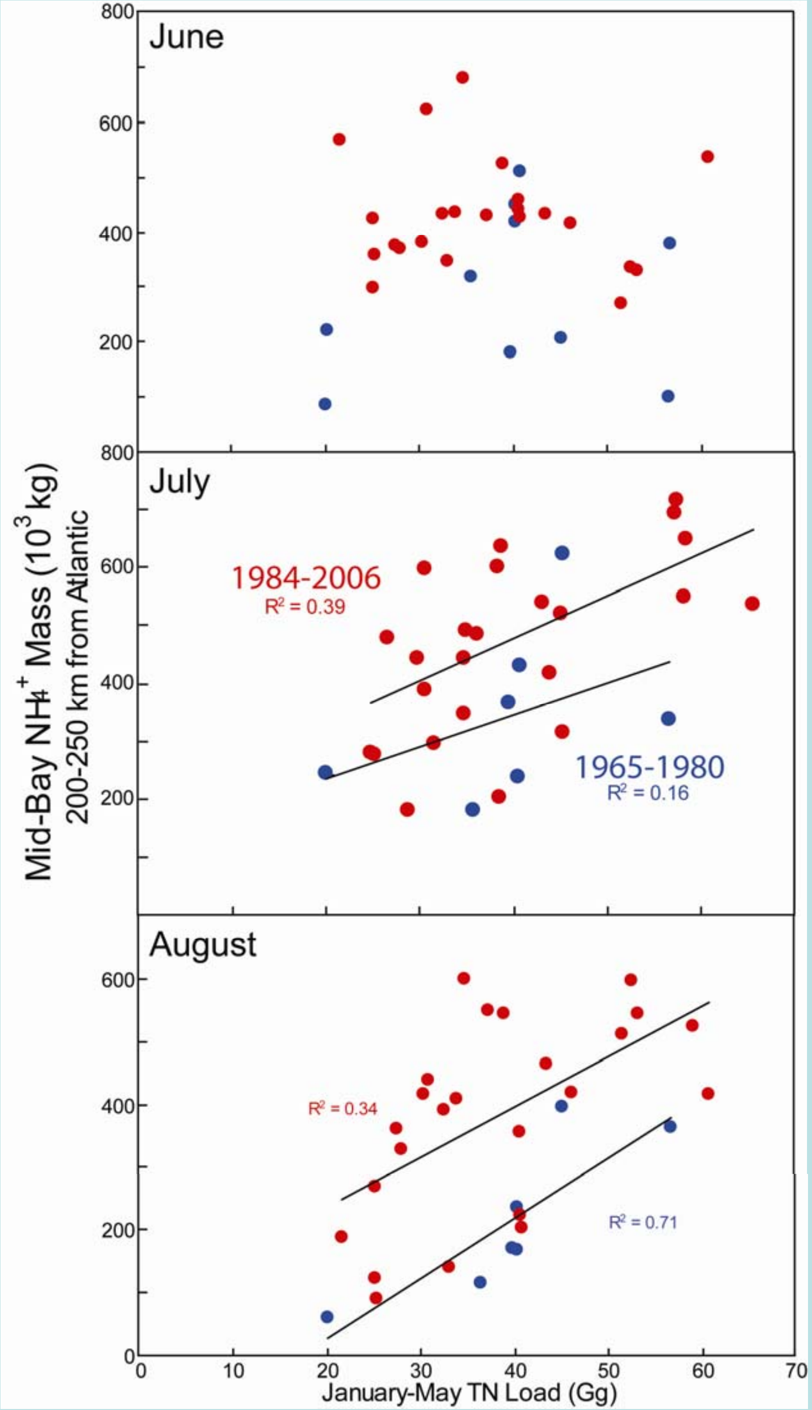


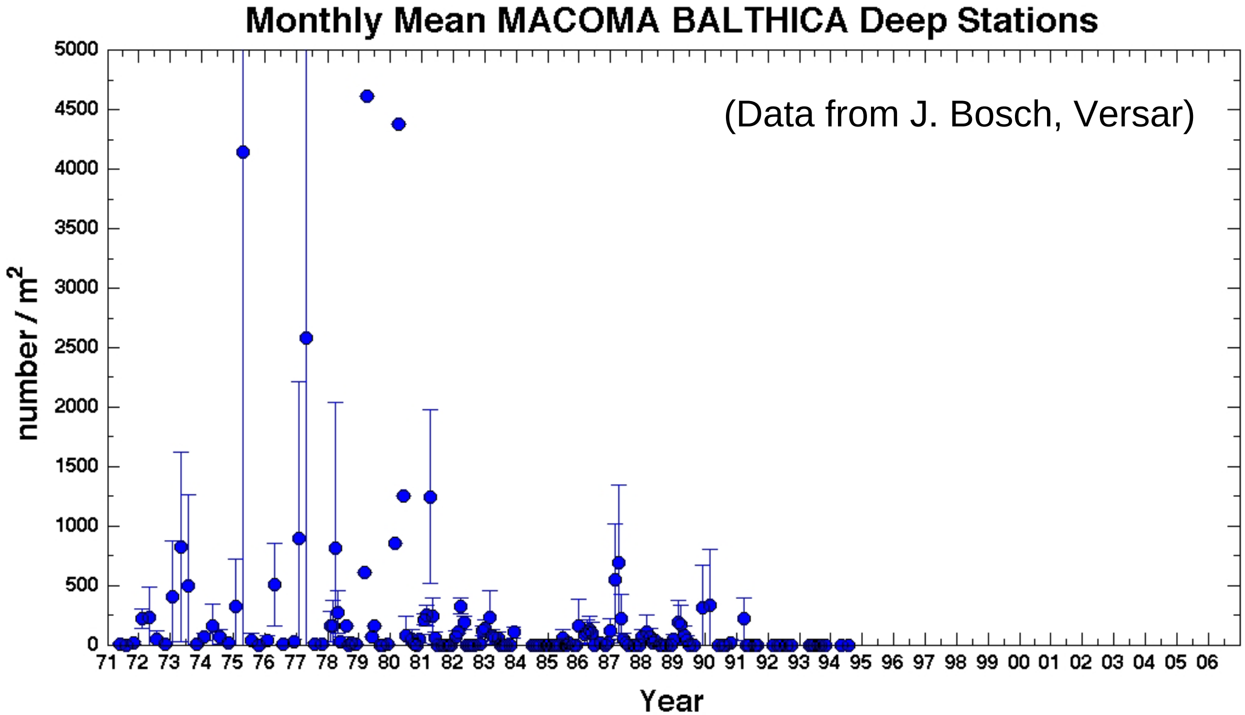
Increase in Bottom Water NH_4 Pools Since mid-1980s

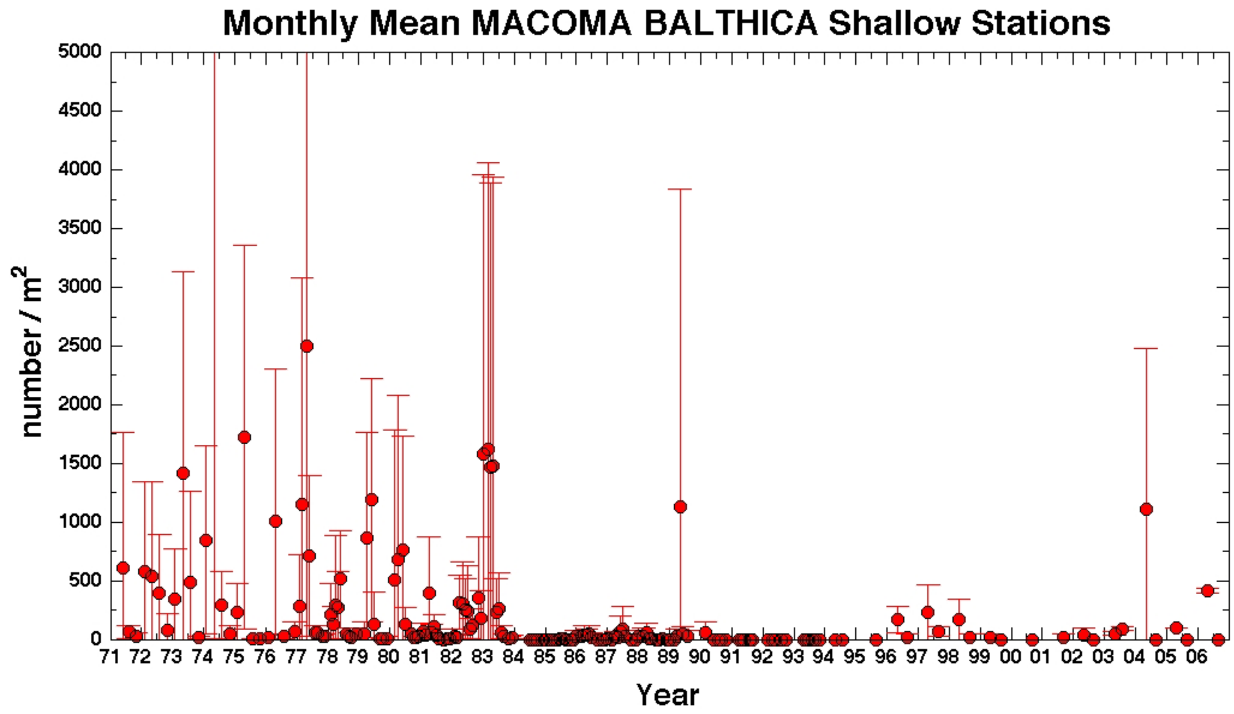
- **Bottom-water NH_4 pools generally increase with TN loading.**

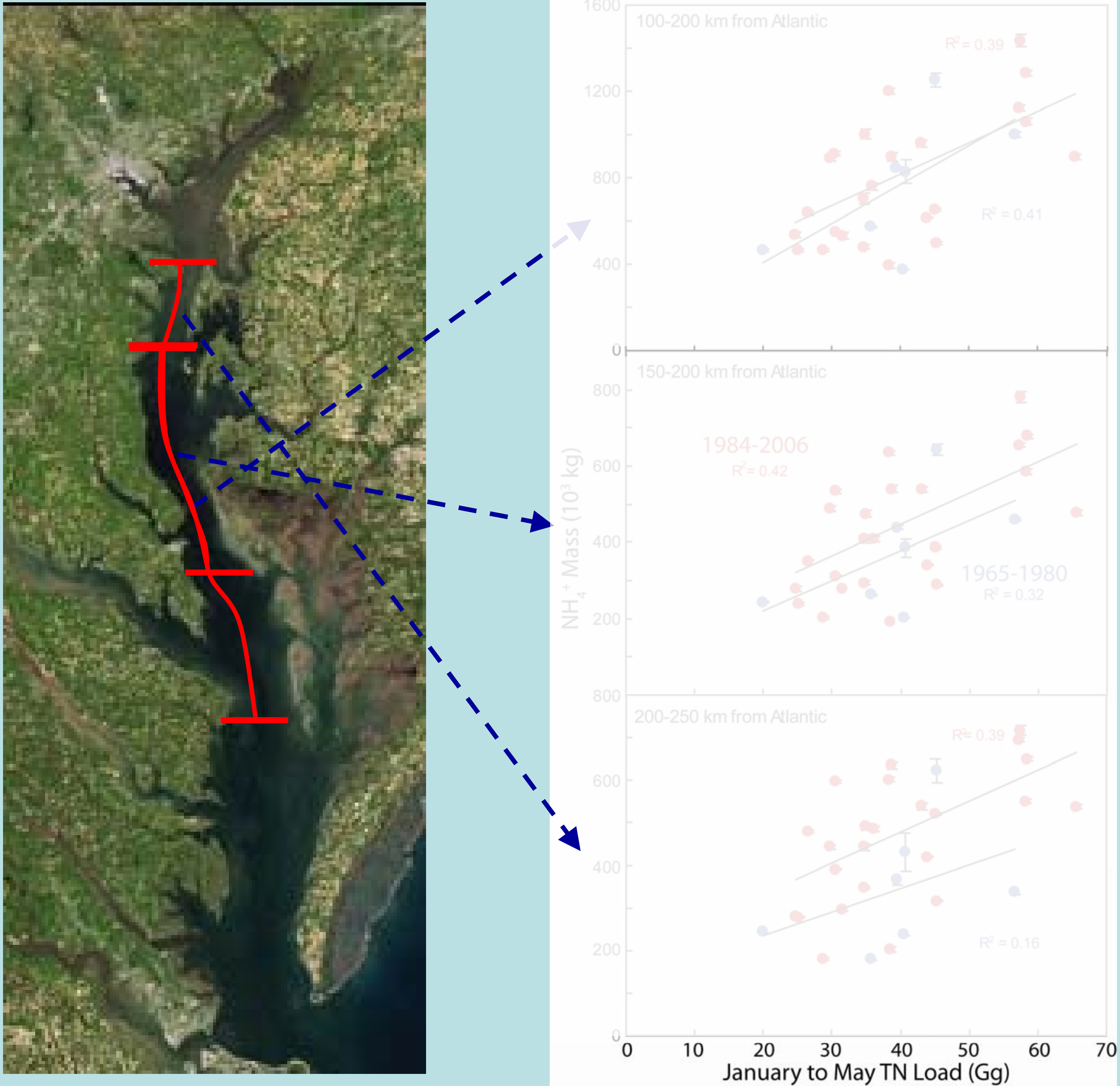
- **In mid-1980s the size of the bottom NH_4 pools increased (~2x) abruptly**

- **Biogeochemical change (hypoxia, macrofauna?)**




Monthly Mean MACOMA BALTHICA Deep Stations
(Data from J. Bosch, Versar)
number / m2
Year
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06


Monthly Mean MACOMA BALTHICA Shallow Stations
number / m2
Year
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06


100-200 km from Atlantic
R² = 0.39
R² = 0.41
150-200 km from Atlantic
1984-2006
R² = 0.42
1965-1980
R² = 0.32
200-250 km from Atlantic
R² = 0.39
R² = 0.16
NH₄⁺ Mass (10³ kg)
0
200
400
600
800
1200
1600
0
10
20
30
40
50
60
70
January to May TN Load (Gg)

Concluding Comments

• Chesapeake hypoxia has grown with Increasing nutrient loading, with abrupt Increase in hypoxia/N-load in early 1980s

• Increase in hypoxia/N-load appears to have caused elevated N recycling (and availability) in the upper-mid Bay, but not other regions

• Cannot conclude that the enhanced N recycling caused the shift in hypoxia/N-load - shifts in other external drivers of hypoxia (climate-related) could be the cause of elevated hypoxia per N-Load

• This work continues
(1) Modeling sediment biogeochemical response to O_2
(2) Computing seasonal N budgets in mid Chesapeake Bay

Acknowledgements

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CBEO Chesapeake Bay Environmental Observatory

demonstrating the transformative power of cyberinfrastructure for environmental science and engineering

NSF

NCCOS

Modeling Hypoxia & Ecological Responses to Climate & Nutrients

CHRP

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