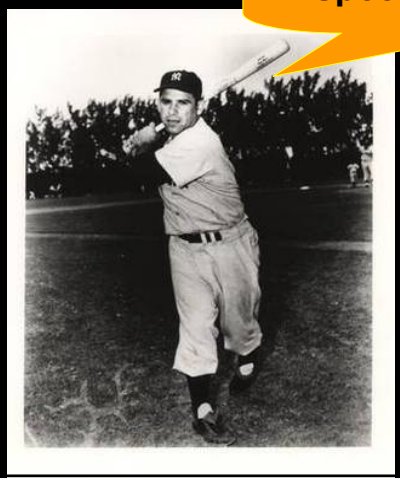
Predicting Coastal Hypoxia:
Application of Occham's Razor

"Prediction is hard.
Especially about the future"



Don Scavia
University of Michigan

Niels Bohr, Yankee Catcher

Forecast Challenge

What N load reduction is needed to reach the environmental goal?

Approaches:

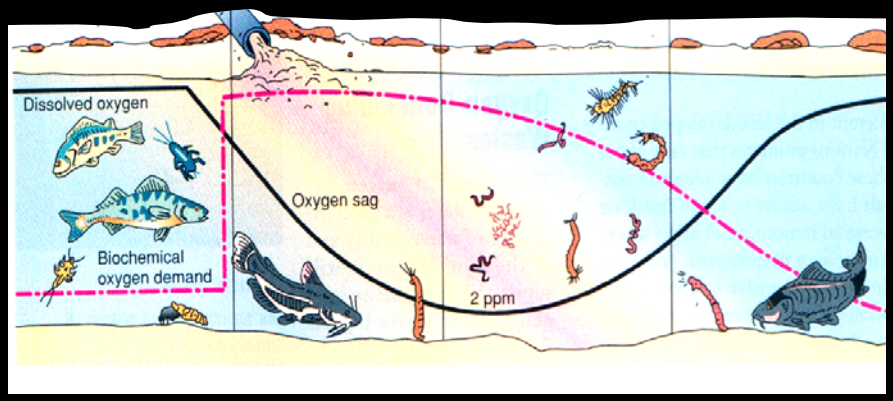
Regression

"Big Scary"

Sweet-spot

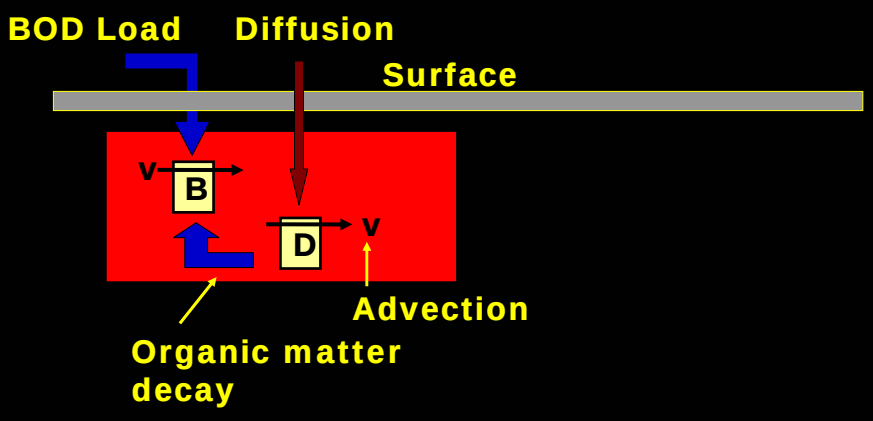
"Sweet spot"

Apply classical engineering river model (Streeter-Phelps DO-sag)



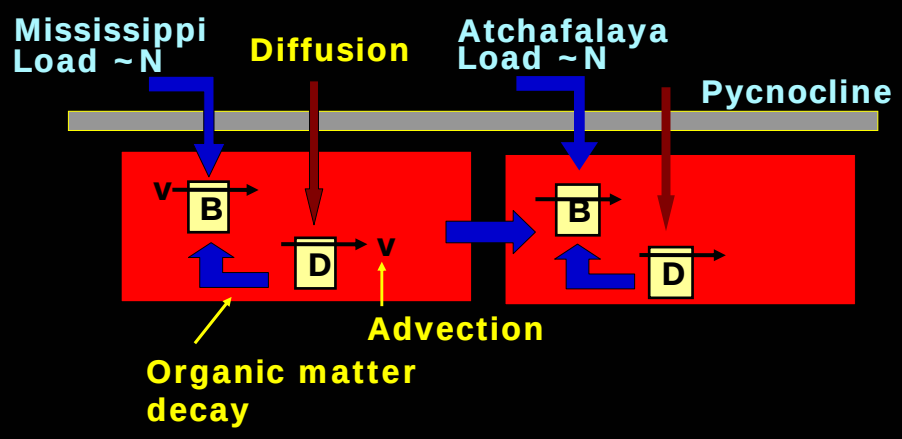
A Simple "river" DO model

B = Organic Matter **D = Dissolved Oxygen**



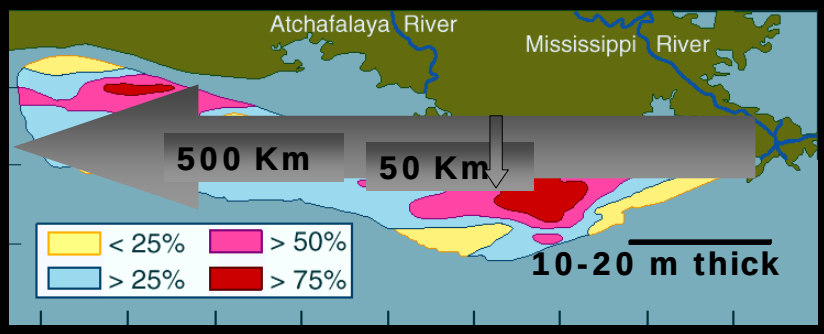
Application to Gulf Hypoxia

B = Organic Matter D = Dissolved Oxygen

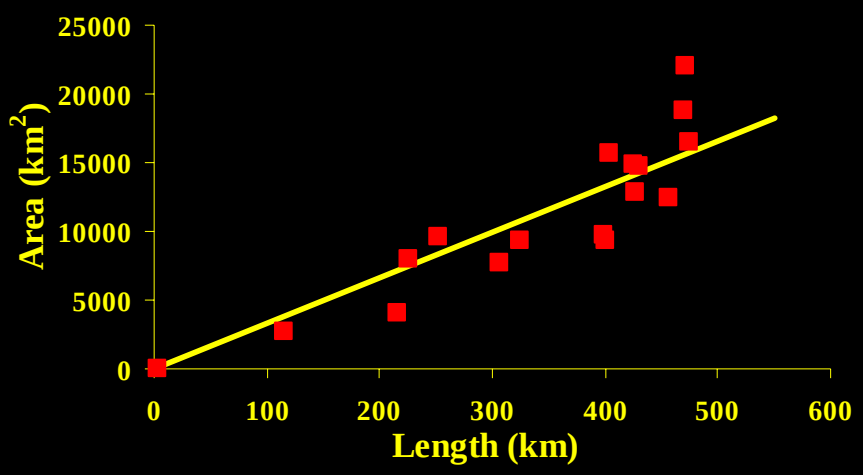


Coastal Bottom Current as a River?

Long-shore currents >> cross-shelf



Most Variation is Along Axis



(A = 33.13L; R^2= 0.79)

Point Source Streeter-Phelps Model

"Downstream" Advection — "BOD" decay

"BOD": $dB/dt = -v\,dB/dx - aB$

DO <u>deficit</u>: $dD/dt = -v\,dD/dx + aB - bD$

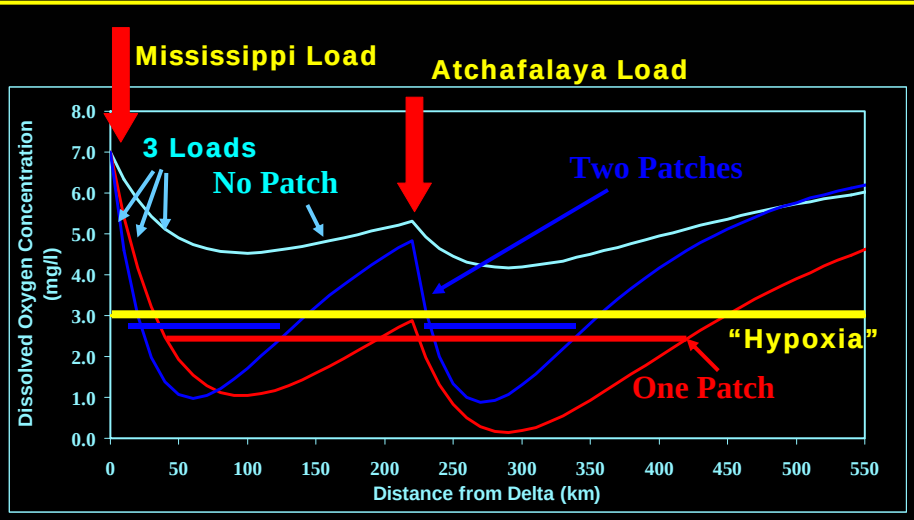
"Reaeration"

Solution at Steady State:

$B = B_o e^{-ax/v}$

$D = a/(b-a)B_o[e^{-ax/v} - e^{-bx/v}]$

Down "River" DO Profiles



Length = Sum of patch lengths

Model Coefficients

- **BOD Load:**
  - Proportional to May-June TN (MT/day)
  - 50% of MS flow goes west
  - C:N from Redfield ratio (algal production)
  - 50% of production settles below pycnocline
  - O:C from respiratory quotient (O_2 consumption)
- **BOD Decay (a):**
  - Proportional to BOD concentration
  - Captures all sub-pycnocline net oxygen-consuming processes
- **Oxygen flux across pycnocline (b):**
  - Proportional to oxygen deficit

Model Coefficients

- **Westward sub-pycnocline "advection":**
  Very few measurements available
  (LATEX measurements for '92, '93, '94)
- **Holding all coefficients constant:**
  $a = 0.003\ d^{-1}$; $b = 0.01\ d^{-1}$; $v = 0.53\ km\ d^{-1}$

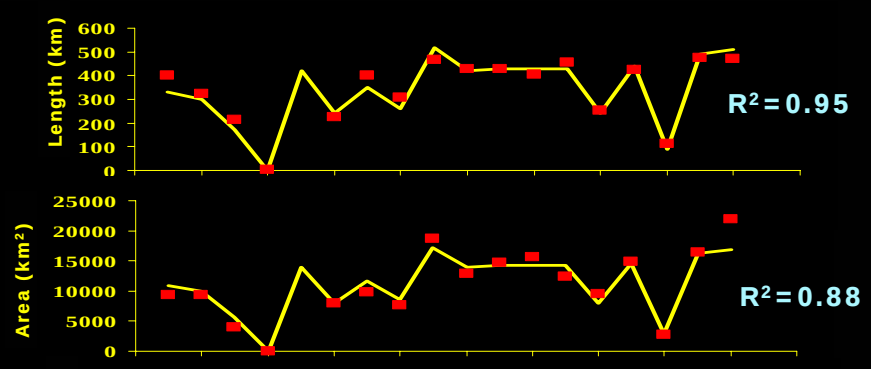
  R^2 (length) = 0.55; R^2 (area) = 0.45

Process:

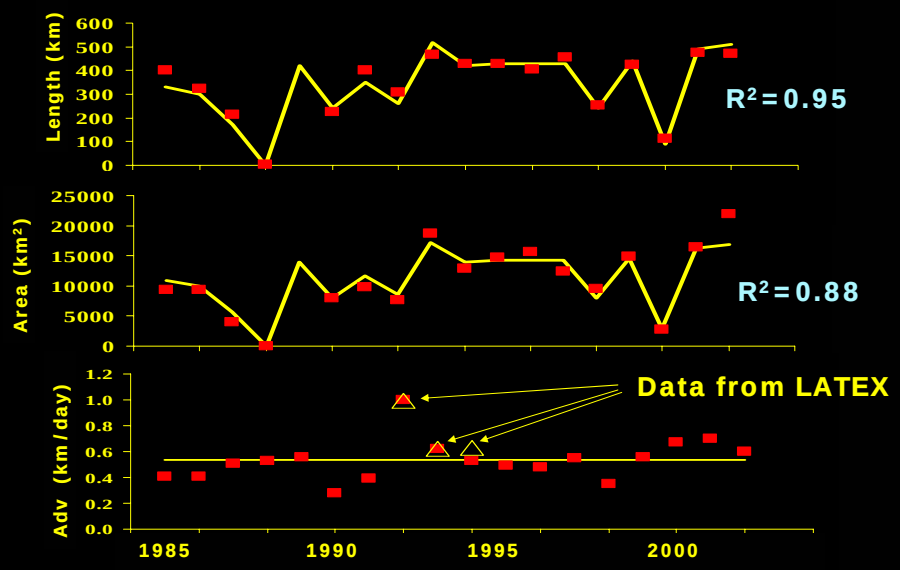
Hold all other coefficients constant.

Adjust "advection" to match observed length and area for each load.

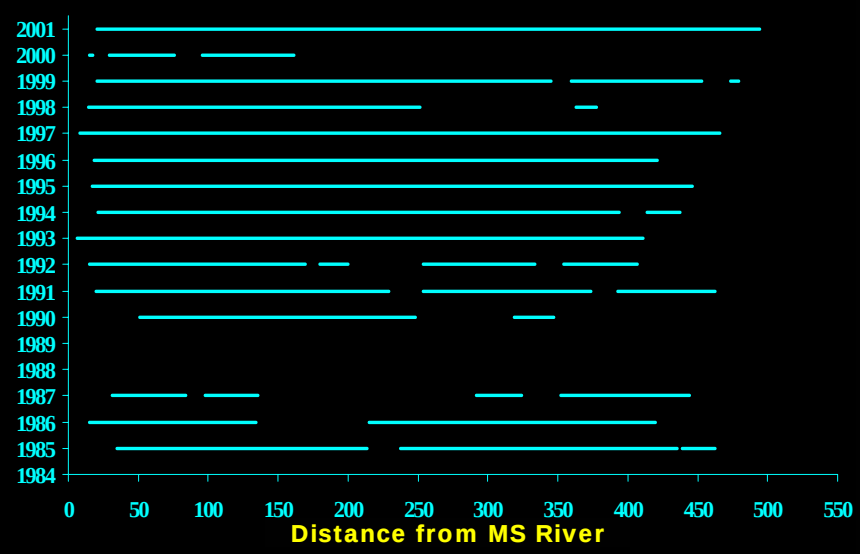
Model Calibration



Model Calibration

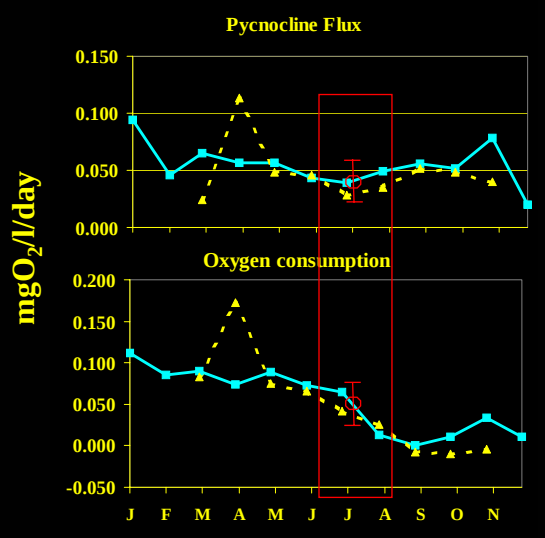


Observed Hypoxia Locations



Simulated Hypoxia Locations

Measured Oxygen Dynamics



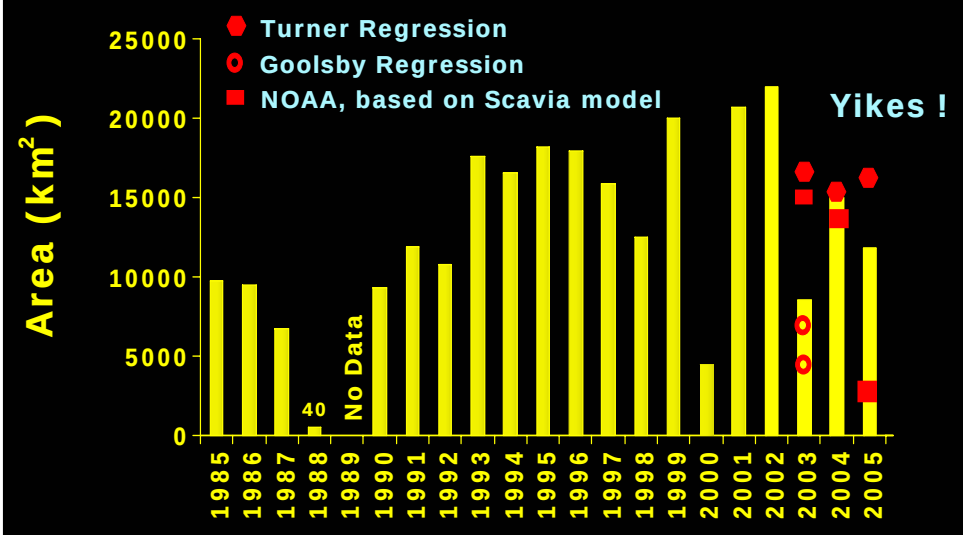
1985-92 mean

1993

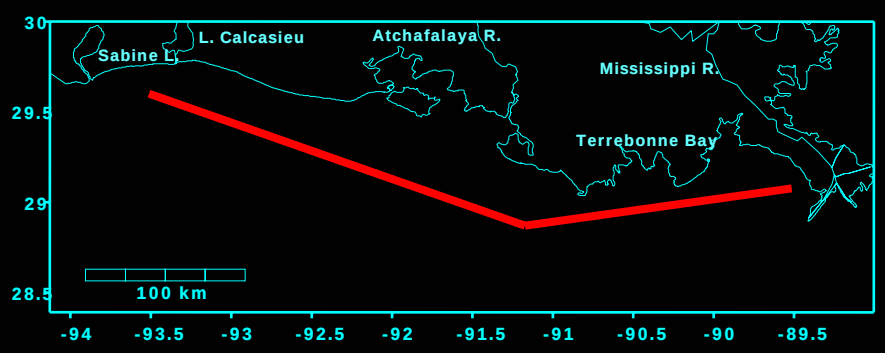
1985-1992 modeled

Justic et al

Forecasts

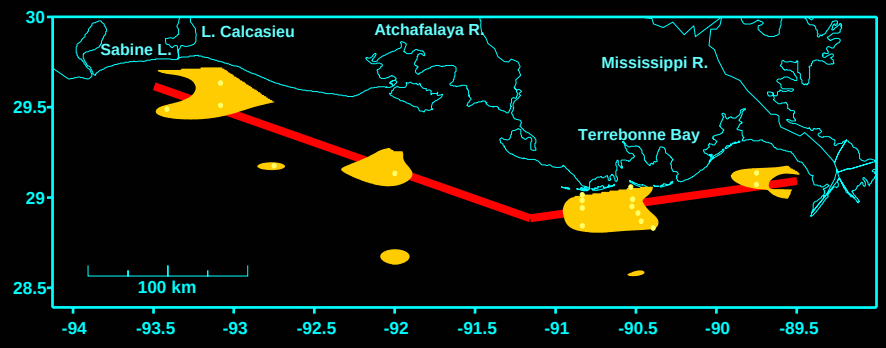


What Happened?



Predicted hypoxic zone length based on May-June Loads and average "v"

Bottom-Water Hypoxia July 23-28, 2003



Dissolved oxygen less than 2 (mg/L)

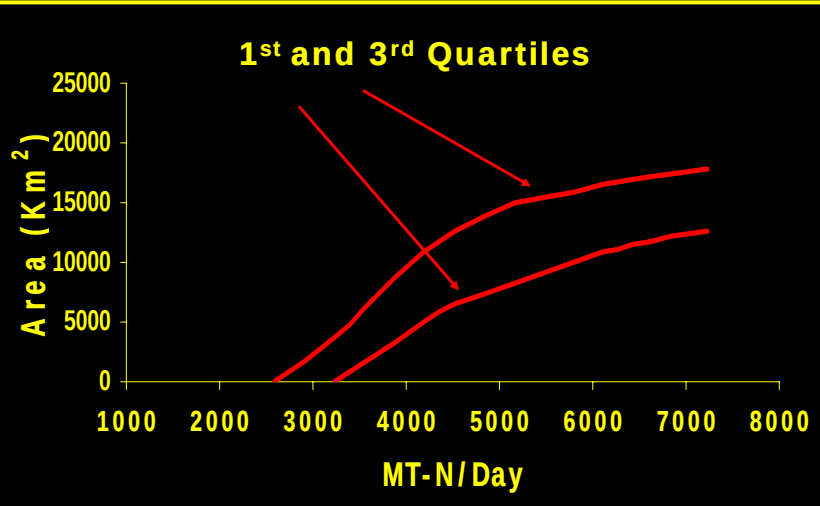
Rabalais, Turner and Wiseman

What happened?

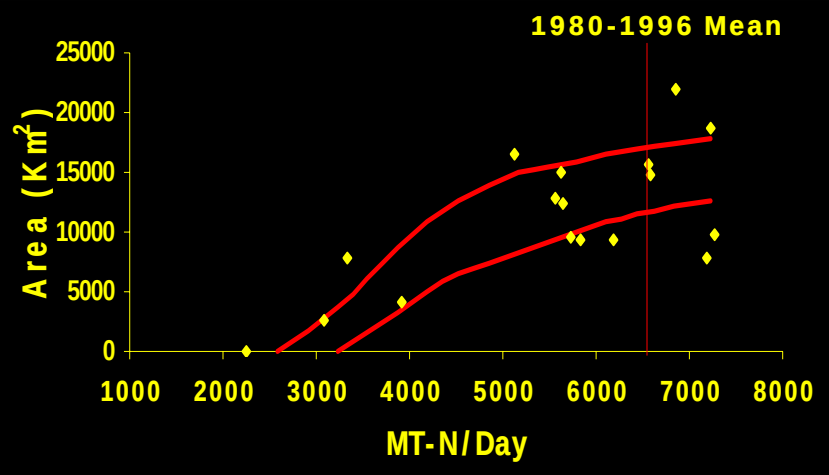
Monte Carlo Simulations

- Select 1000 advection values (v)
  Normal Distribution
  X ± s from the 17 calibrated values
  (0.53 ± 0.16 km/day)
- Hold all other coefficients constant
- Run model 1000 times for each load
- Report output statistics.

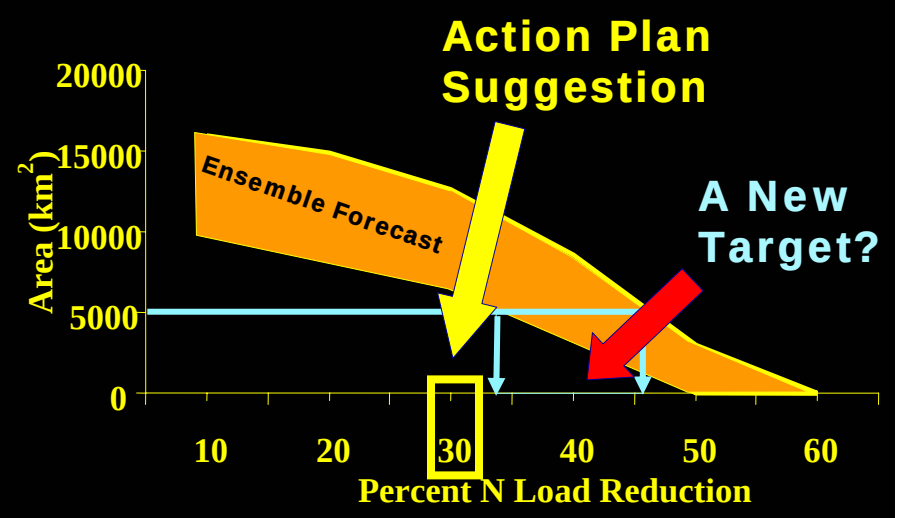
Forecast Scenarios



Forecast Scenarios



Effects of Reduced Load



Two Big Questions

When did large-scale hypoxia start?

What is the required N load reduction to get there?

Compare 3 Models

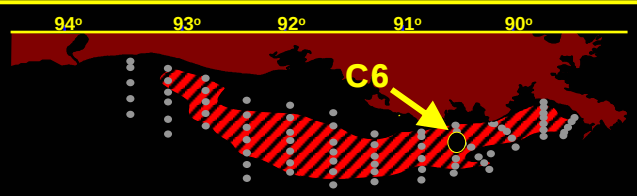
- Justic et al.

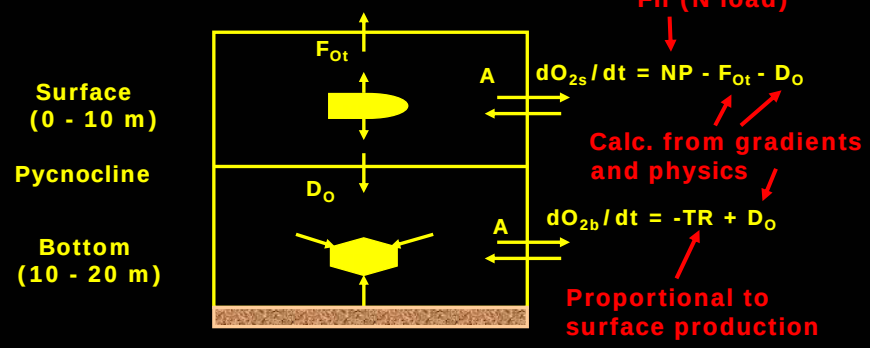
  1D vertical oxygen flux model
- Bierman et al

  3D eutrophication model
- Scavia et al.

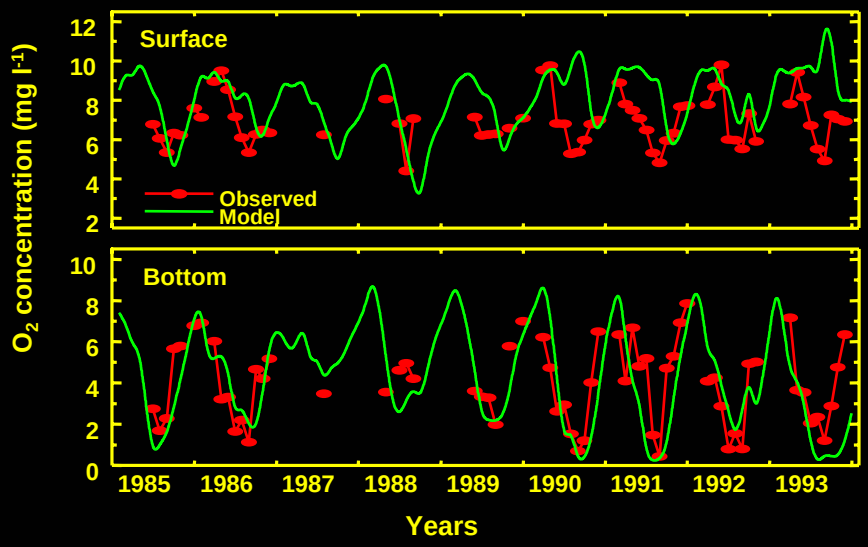
  1D horizontal DO flux model

Justic et al.



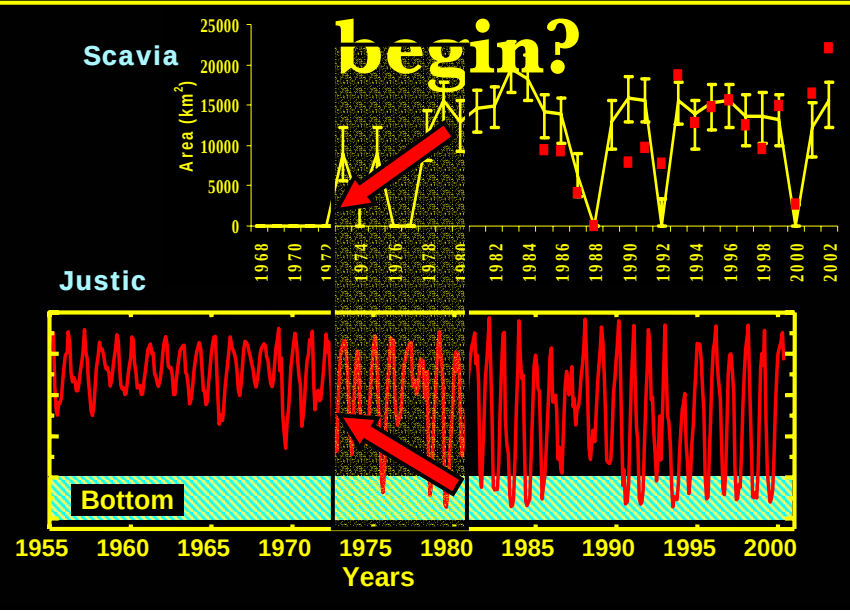


Model Calibration

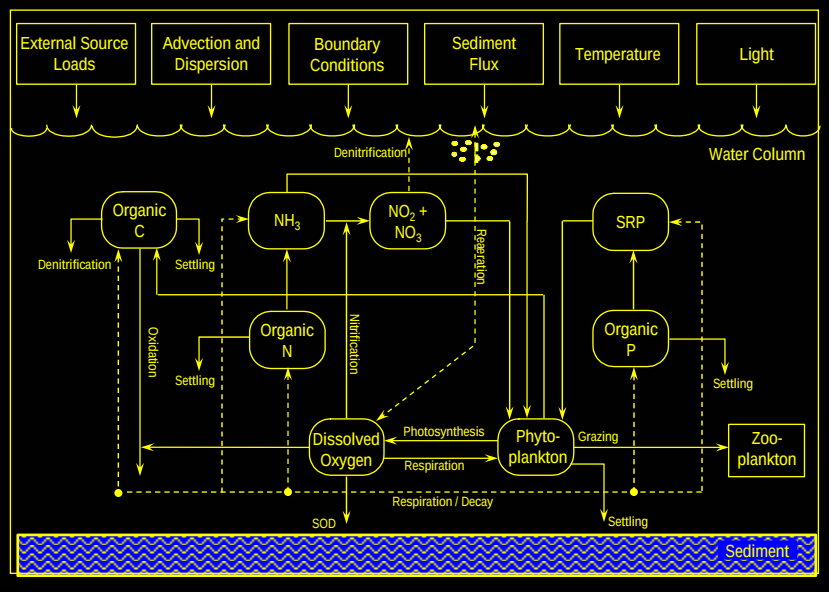


Justic et al., 2002

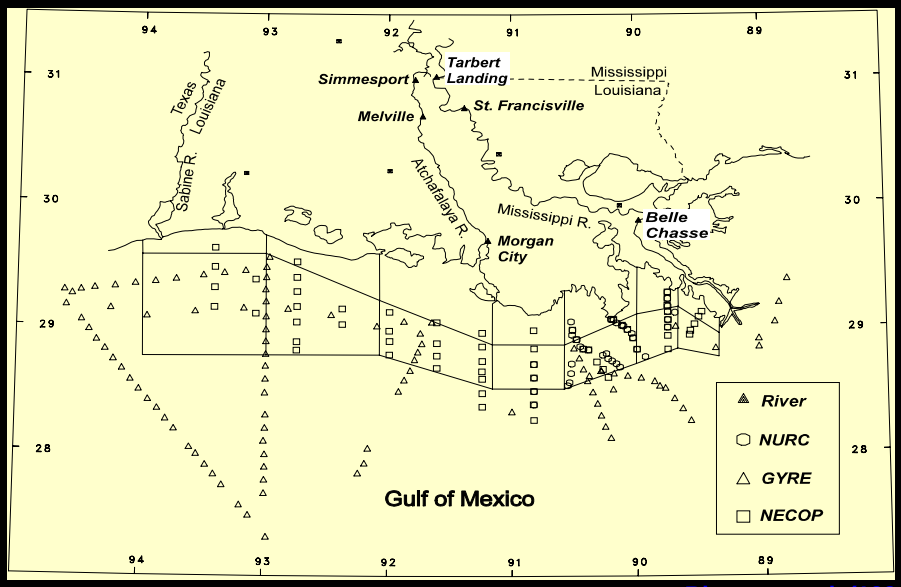
When did hypoxia begin?



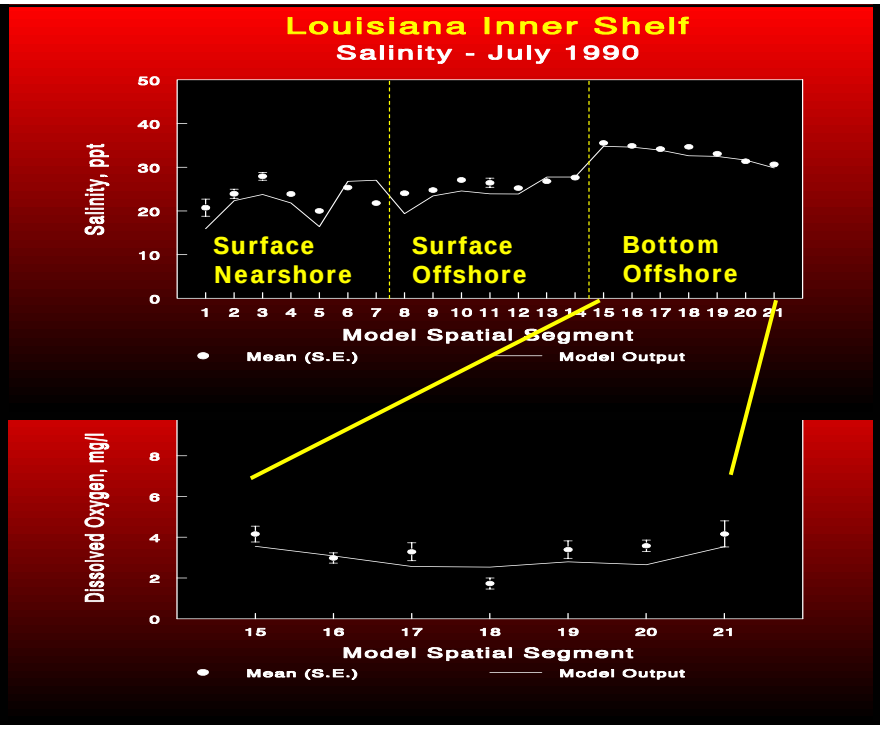
Bierman et al.



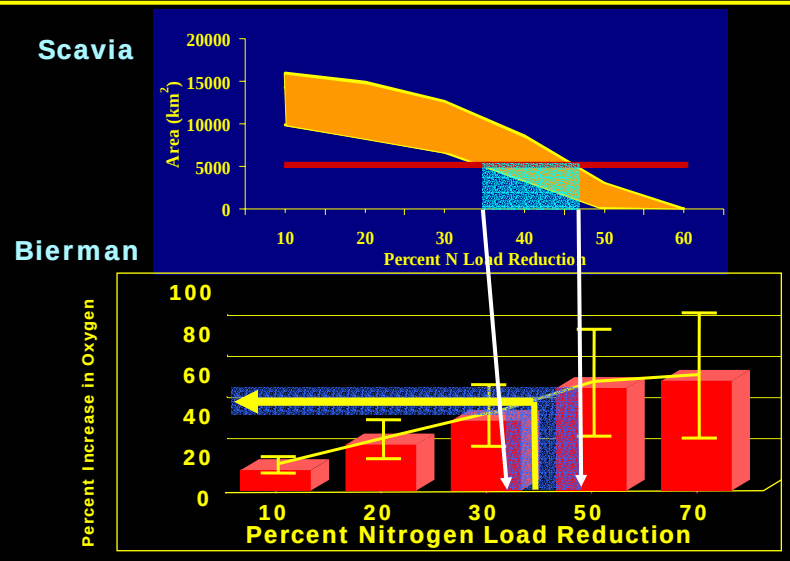
Bierman 3D Box Model



Bierman et al. (1994)



N load



Summary

- Substantial agreement among different models.
- Hypoxia became significant only in the 1970's.
- 35-45% N reduction needed to meet goal.

Take Home Messages

Make forecasts that people need

- Interannual variability?
- Long-term trends?

Match forecast and driver scales

- Management decisions are decadal

Understand uncertainties

- Model structure/coefficients
- Environmental variability