Application Of Data Mining And Statistical Learning Approaches For Insights Into Dissolved Oxygen

Delaware Estuary Science & Environmental Summit
January 25-28, 2015
Cape May, NJ

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This Presentation

- Motivation for this effort
- The Data Sets
- Identification of Temporally Optimal Explanatory Variables
- The 3 resulting models
- Climate change assessment
- Interpretation and Conclusions

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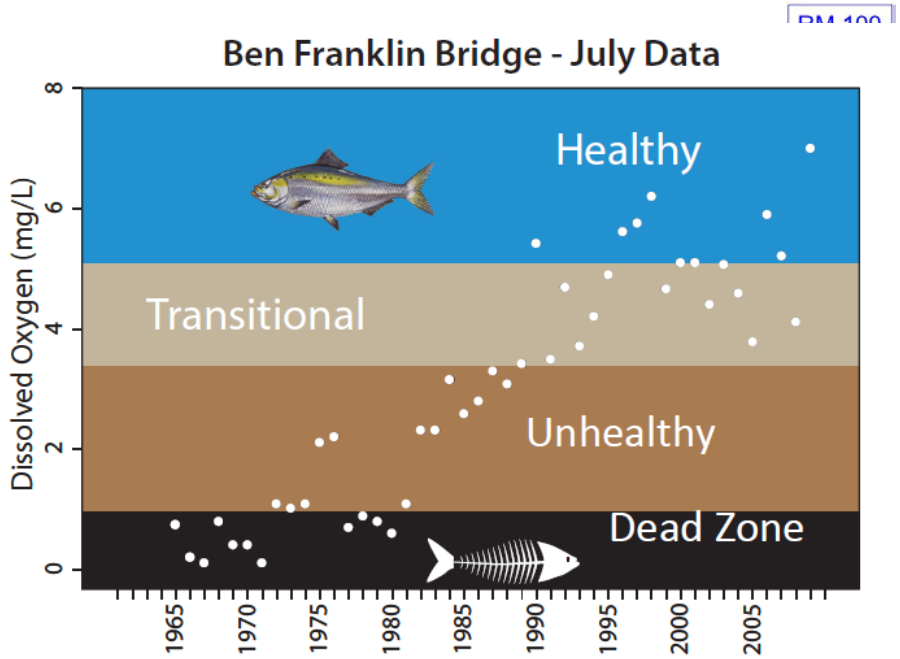
Status of Oxygen in the Delaware Estuary



- Designated use ≠ existing use, EPA Nov. 2009 at WQAC;
- Atlantic Sturgeon listed as endangered species, Feb. 2012;
- Delaware Riverkeeper, others, petition DRBC to upgrade uses, revise criteria, March 2013;
- STAC issues DO brief, current criteria too low for sturgeon, Feb. 2014;
- Delaware River Basin Fish and Wildlife Management Cooperative letter to DRBC to increase DO criteria, April 2014.

Action Moving Forward

- Nutrient Criteria Development Plan
  - Eutrophication model;
    - Deterministic model accounting for enough of the physical, chemical, biological processes to be able to link management scenarios to system response;
    - Long term;
    - High effort;

  - Data Mining & Statistical Learning Exercise (this project);
    - Can **not** be used to link management & system response (more later);
    - May (or may not) inform the Eutrophication model about important drivers, conditions;
    - Some additional insight (?);
    - Relatively quick;
    - Relatively low effort;

1. Multiple term linear regression model;
2. Regression tree model;
3. Random Forest model.

Data Mining & Statistical Learning

- Statistical learning – set of tools for modeling and understanding complex data sets *(James et al., 2013)*;
- Data mining - computational process of discovering patterns in large data sets involving interdisciplinary methods and tools

  (adapted from http://en.wikipedia.org/wiki/Data_mining)
- Extracting knowledge from data collected for ***other purposes***;

Daily Data 2000 through 2010

- Median tidal elevation at Philadelphia;
- Minimum tidal elevation at Philadelphia;
- Maximum tidal elevation at Philadelphia;
- Tidal Range at Philadelphia;

- Air Temperature Mean at PHL;
- Air Temperature Max PHL;
- Air Temperature Min PHL;
- Dewpoint PHL;
- Precipitation Total PHL;
- Wind gust PHL;
- Relative Humidity PHL;
- Mean Wind PHL;
- Barometric Pressure PHL;
- Wind Direction PHL;
- Maximum Wind PHL;

- Daily radiation total at PHL;

National Solar Radiation Data Base

1991- 2010 Update

No loadings!

- Discharge at Trenton;
- Specific conductance at Trenton;
- DO Sat. at Trenton;
- pH Median at Trenton;
- pH Range at Trenton;
- Water Temperature Mean at Trenton;
- Specific Conductance Max at Ben Franklin;
- Specific Conductance Min at Ben Franklin;
- Specific Conductance Mean at Ben Franklin;
- Specific Conductance Range at Ben Franklin;
- pH Max at Ben Franklin;
- pH Min at Ben Franklin;
- pH Median at Ben Franklin;
- pH Range at Ben Franklin;
- Water Temp Min at Ben Franklin;
- Water Temp Max at Ben Franklin;
- Water Temp Mean at Ben Franklin;
- Water Temperature Range at Ben Franklin;
- DO Sat. at Ben Franklin;

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Temporal Complexity Problem

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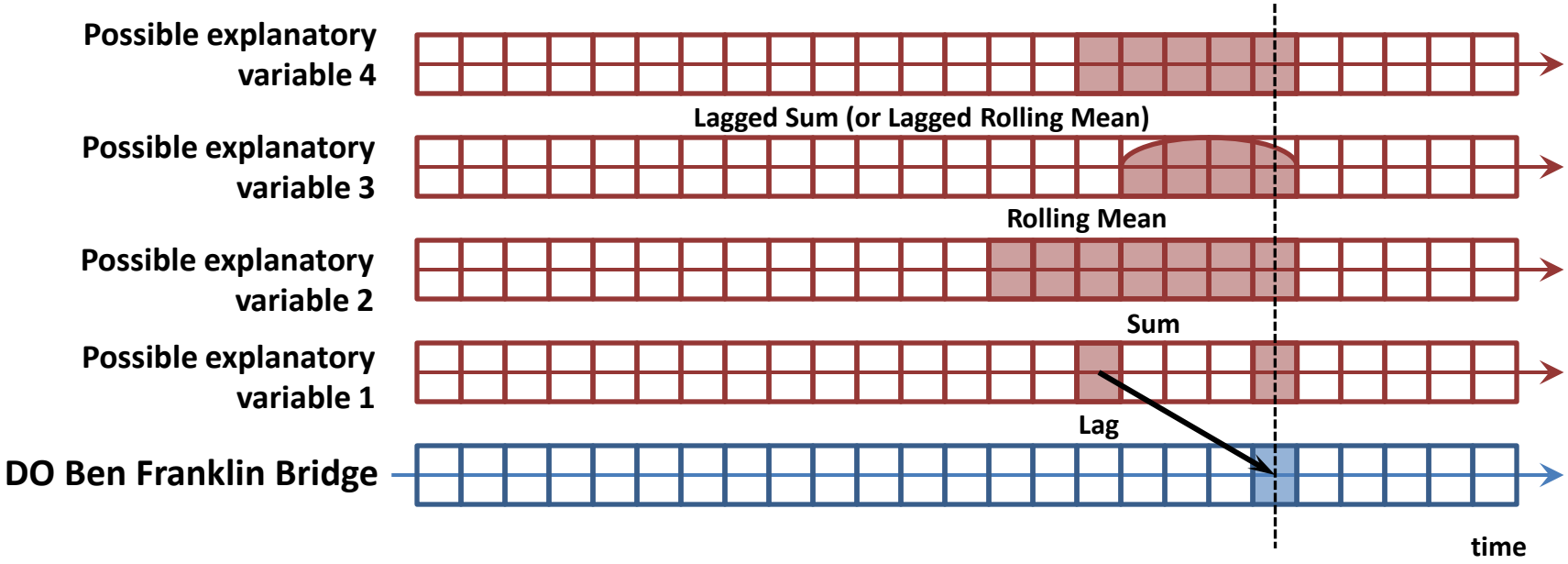
Video Link



Select Raw and Temporally Optimized Variables

Raw Variable	R^2	Temporally Optimized Version	R^2
Radiation	0.009	Radiation_Mean_27_Lag_5	0.220
AirTempMax	0.298	AirTempMax_Sum_22_Lag_5	0.622
DewPoint	0.325	DewPoint_Sum_22	0.566
dischargeTrenton	0.126	dischargeTrenton_Sum_30	0.353
MaxWind	0.027	MaxWind_Mean_26	0.292
spcTrenton	0.324	spcTrenton_Mean_16	0.413
MeanWind	0.026	MeanWind_Mean_27	0.343
tempTrenton	0.525	tempTrenton_Mean_16_Lag_4	0.686

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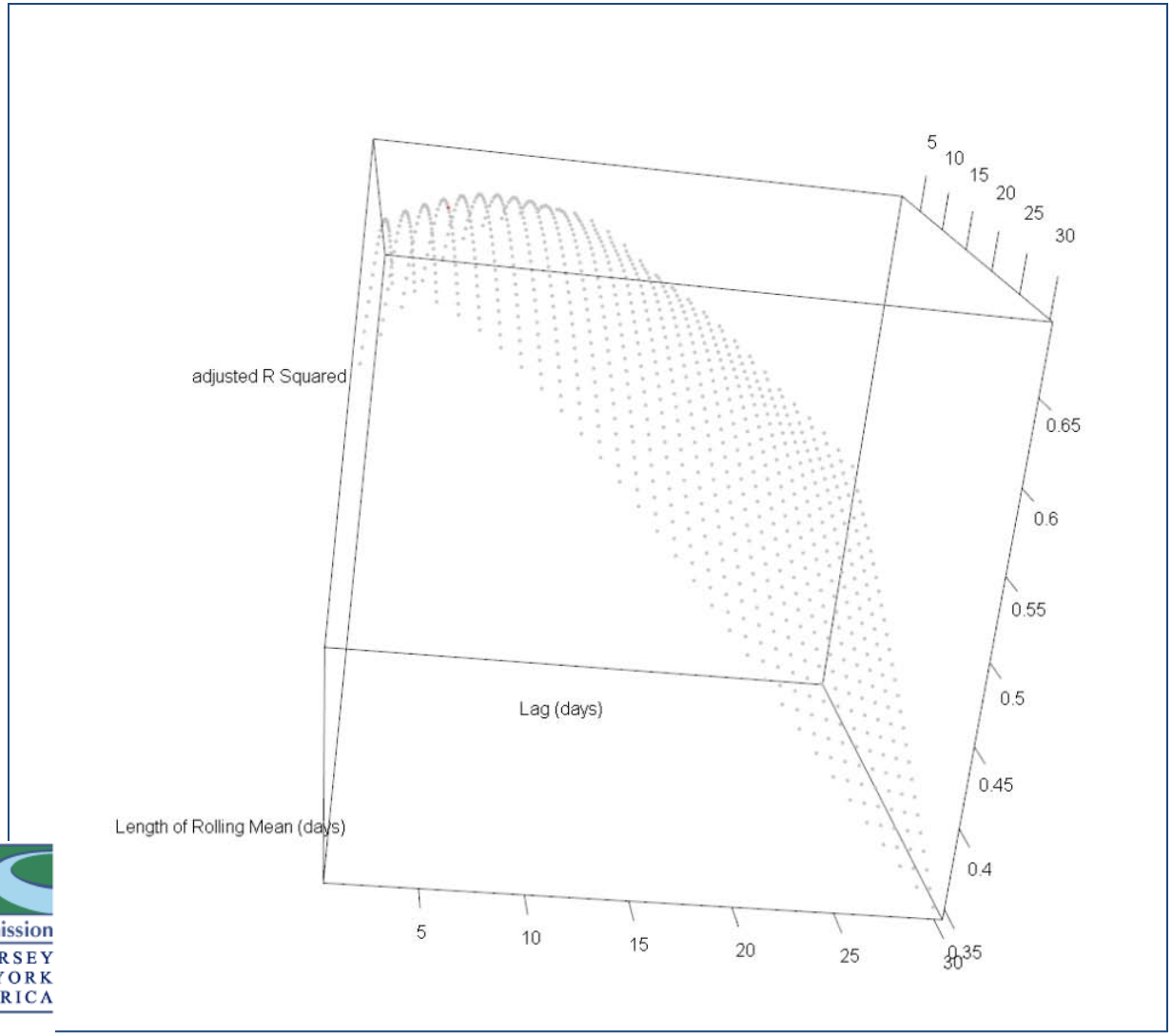
Computed R^2 value has Structure in response to variation and Rolling Mean and Lag

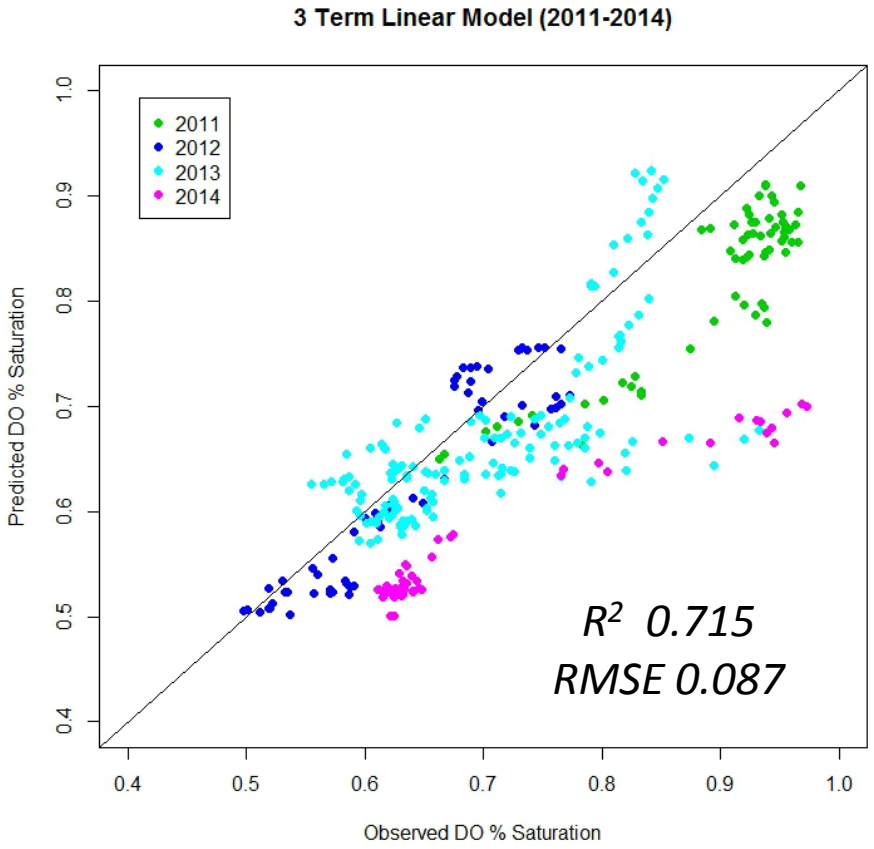


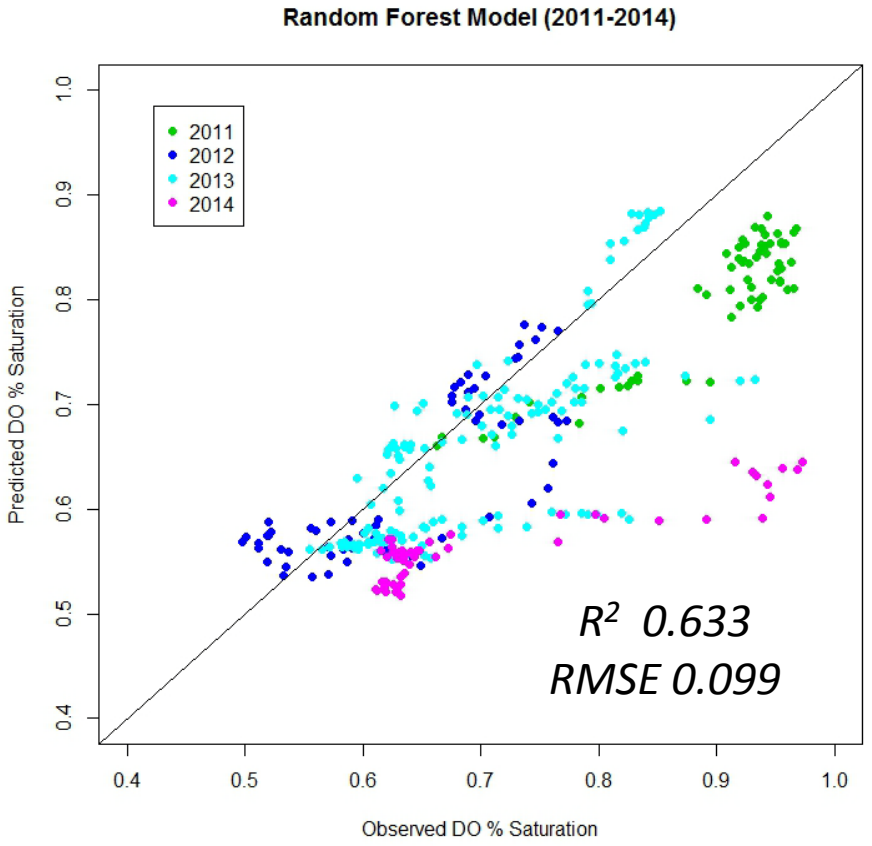
Video Link

The Resulting Models

- Linear Regression Model (3-Term);
  - Any term could be squared or logged (but not both);
  - 8.5 Million possibilities;
  - Cycled through all 8.5 Million to identify the best possible within the training set;
- Regression Tree (interim step toward….);
- Random Forest Model;

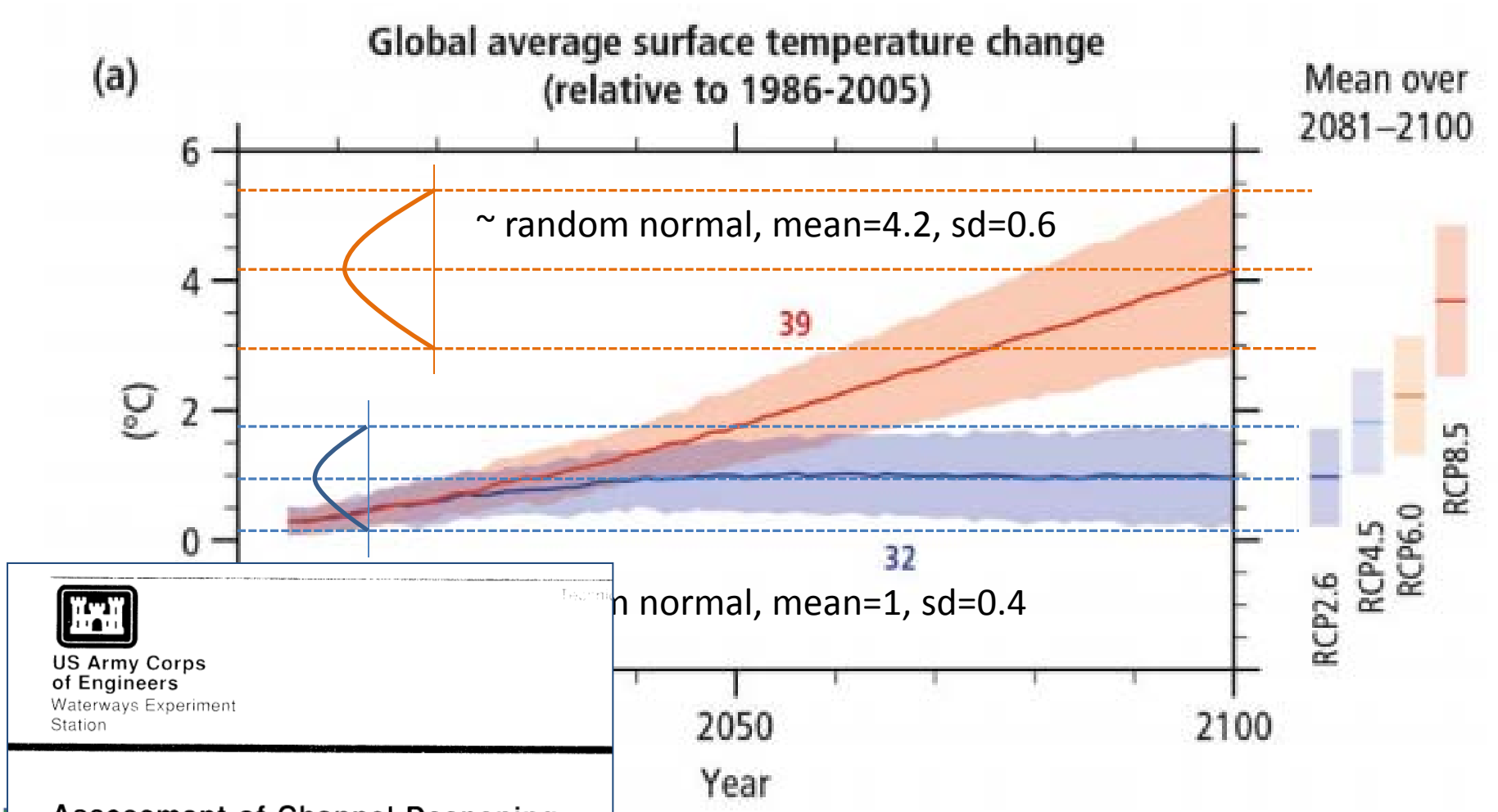
Model Performance
2011-2014 data (i.e. out of sample)





$DOSatBF = 4.862E^{-1} - 1.089E^{-2} \times TempMeanBF + 1.205E^{-2} \times pHMedianBF^2 - 4.468E^{-6} \times spcTrenton\_Mean\_16^2$

Probing the models for Climate Change



US Army Corps
of Engineers
Waterways Experiment
Station

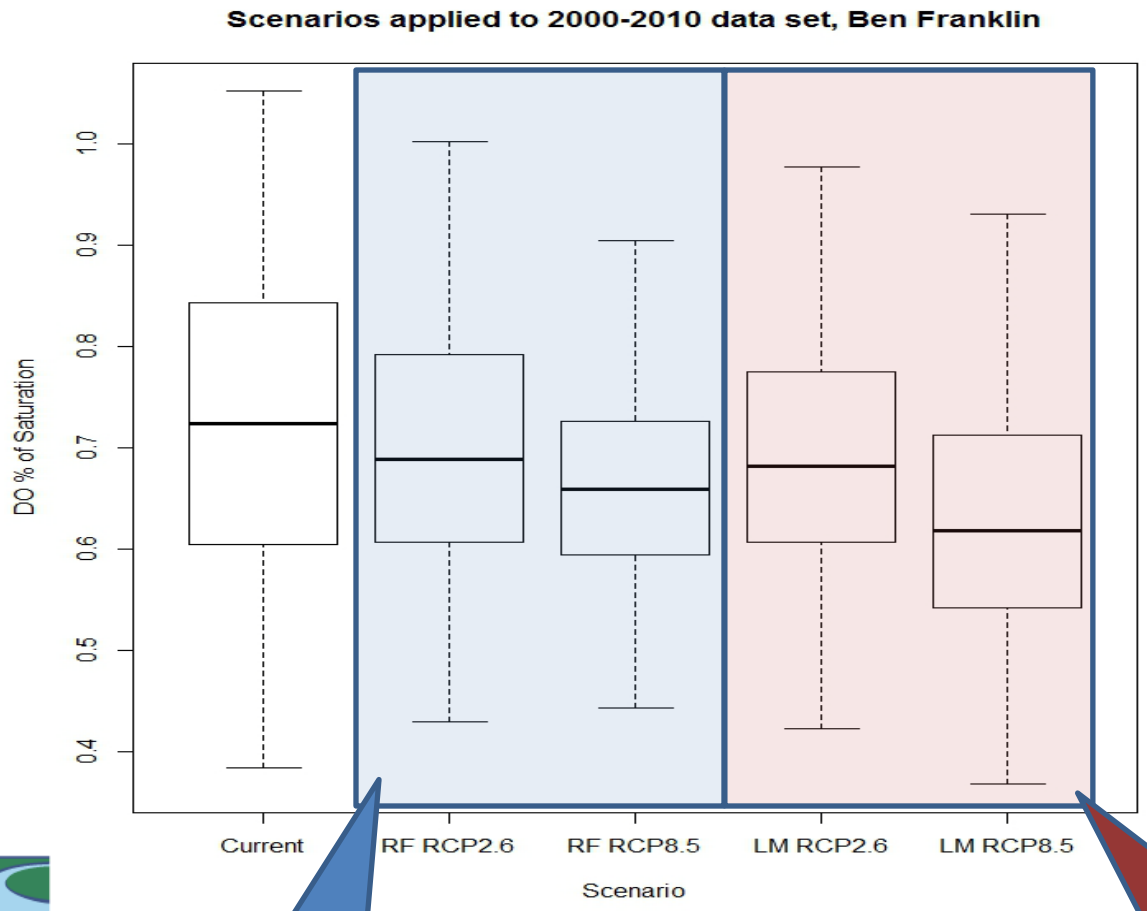
Assessment of Channel Deepening in the Delaware River and Bay

A Three-Dimensional Numerical Model Study

by Keu W. Kim, Billy H. Johnson

Source: Climate Change 2014 Synthesis Report. Intergovernmental Panel on Climate Change. www.ipcc.ch Retrieved Dec. 22, 2014.

Climate Change Probe Results



Random Forest

3-Term Linear Regression

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Interpretation

- Both forms (3-Term LM and Random Forest) responsive to various expressions of temperature;
- Results suggest an un-accounted for variable (especially important in summer 2014);
- Re-emphasizes the need for deterministic Eutrophication model;
- Both forms unsuccessful at Chester;
- Probably not sufficient for forecasting;
- Climate change likely to exert downward pressure on dissolved oxygen at Ben Franklin;

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Questions?

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