4-16-2014

The estuarine hypoxia component of the Coastal Ocean Modeling Testbed (COMT)

Marjorie Friedrichs
Virginia Institute of Marine Science

Lyon Lanerolle
Coast Survey Development Laboratory, NOAA/NOS

Carl Friedrichs
Virginia Institute of Marine Science

Raleigh Hood
Woods Hole Oceanographic Institution

The Estuarine Hypoxia Component of the Coastal Ocean Modeling Testbed (COMT)

Lyon Lanerolle (NOAA CSDL)

and the

Estuarine Hypoxia COMT team

A Community Coastal and Ocean Modeling Testbed (COMT)

to Improve Understanding and Operational Forecasts of Extreme Events and Chronic Environmental Conditions Affecting the U.S.

Five Teams:

→ 1) Chesapeake Bay Estuarine Hypoxia Forecasting

2) Integration of West Coast Operational Coastal & Ocean Models

3) Puerto Rico/US Virgin Islands Inundation & Wave Forecasting

4) Northern Gulf of Mexico Ecological Forecasting

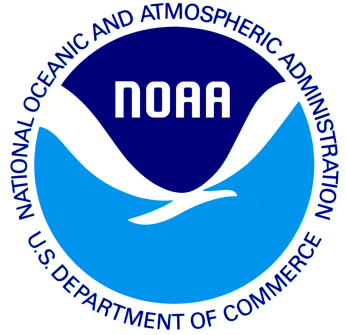
5) Cyberinfrastructure

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE

IOOS® INTEGRATED OCEAN OBSERVING SYSTEM

The Estuarine Hypoxia COMT Team

VIMS: Marjy Friedrichs (lead PI)
Carl Friedrichs (VIMS-PI)
Ike Irby (funded student)
Aaron Bever (consultant)
Jian Shen (collaborator)
Cathy Feng (collaborator)
NOAA-CSDL: Lyon Lanerolle (NOAA-PI)
Frank Aikman (collaborator)
WHOI: Malcolm Scully (WHOI-PI)
UMCES: Raleigh Hood (UMCES-PI)
Hao Wang (funded student)
Wen Long (collaborator)
Jeremy Testa (collaborator)



Estuarine Hypoxia Objective

To assess the readiness and maturity of a suite of existing coastal ecological community models for determining past, present and future hypoxia events within the Chesapeake Bay, in order to **accelerate the transition of hypoxia model formulations and products from "academic research" to "operational centers"**

Chesapeake Bay EH centers include:

- NOAA/NOS/CO-OPS
- Chesapeake Bay Ecological Prediction System (CBEPS)
- EPA Chesapeake Bay Program (CBP)

Estuarine Hypoxia Goal

Compare multiple models within the Estuarine Hypoxia Testbed in order to improve existing:

1. **CBOFS short-term forecasting:** by incorporating new oxygen and physical model enhancements into the existing operational NOAA CO-OPS Chesapeake Bay Operational Forecast System (CBOFS) for evaluation during their next update

2. **CBEPS short-term forecasting:** by developing a 24/7 predictive capacity for nowcasting/forecasting of oxygen/hypoxic volume as part of CBEPS at the NOAA CBPO and UMCES

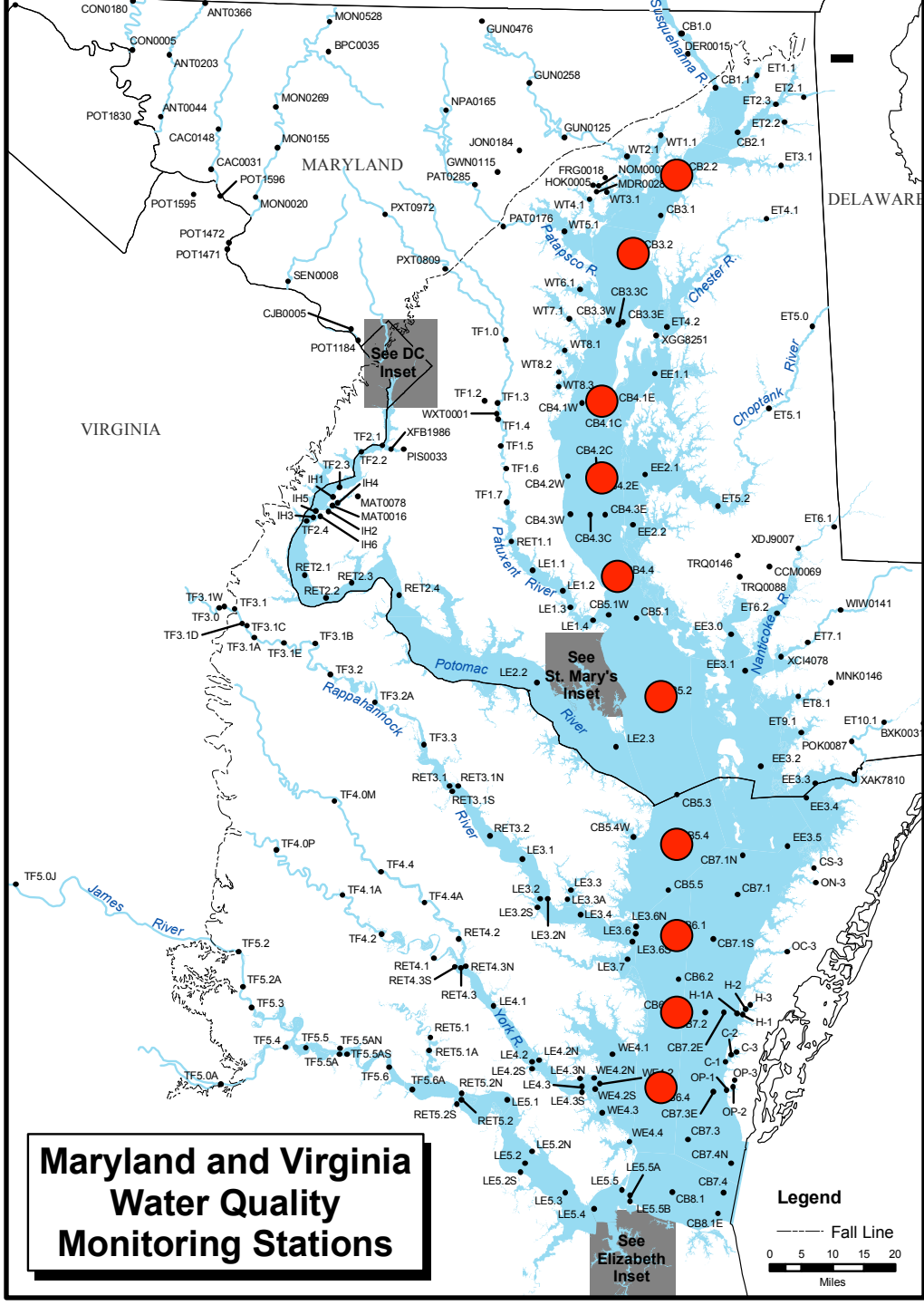
3. **CBP scenario-based forecasting:** Apply the official CBP nutrient reduction strategies to COMT models to determine whether they perform similarly to the regulatory CBP model in terms of predicting the effect of reduced nutrients on hypoxia

Model Comparisons via Chesapeake Testbed

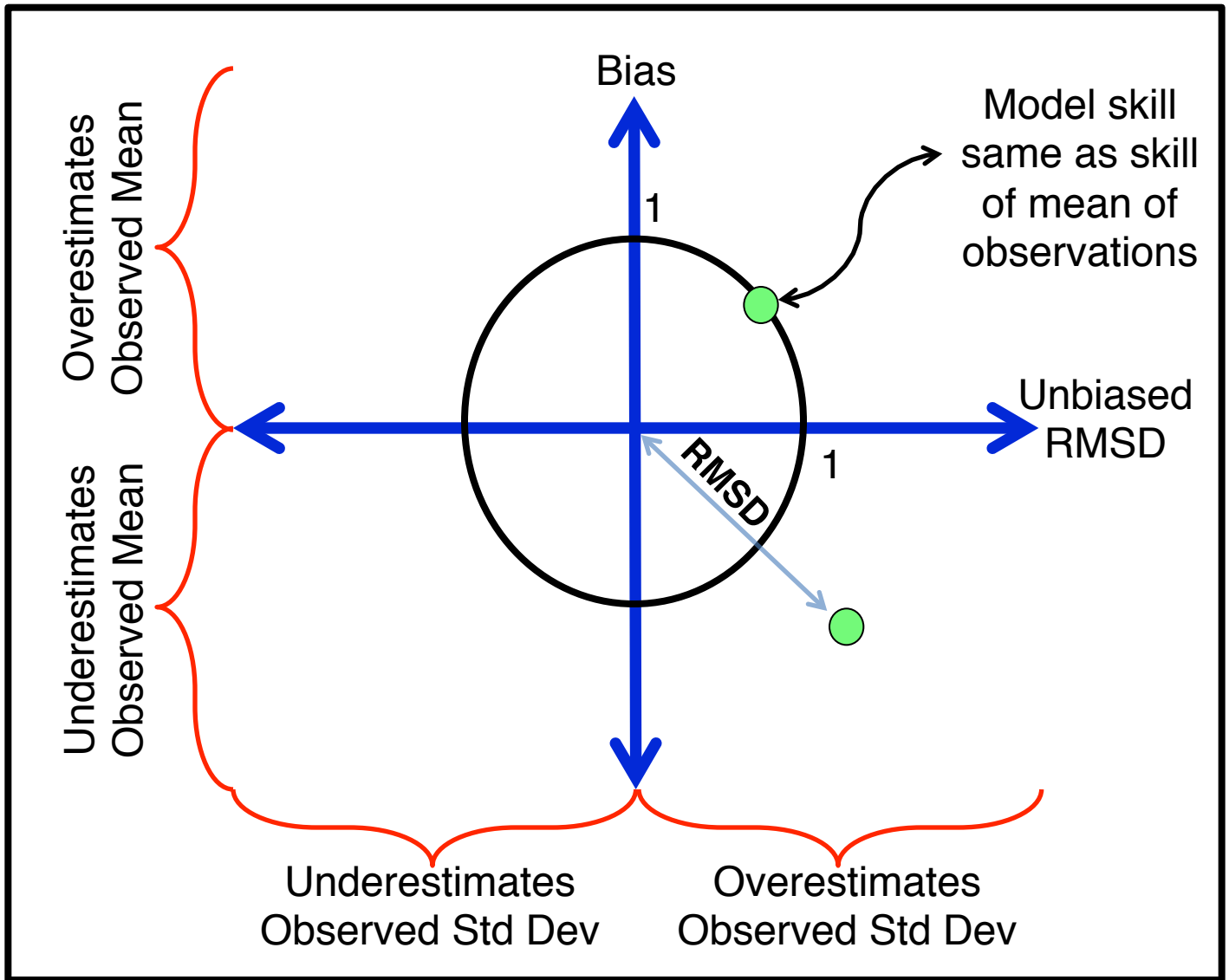
- Statistically compare output from four Chesapeake Bay models:
  - three ROMS models, varying biological complexity
    (ChesNENA, ChesROMS-BGC, ROMS-RCA)
  - biologically sophisticated CBP regulatory model
    (CH3D-ICM)

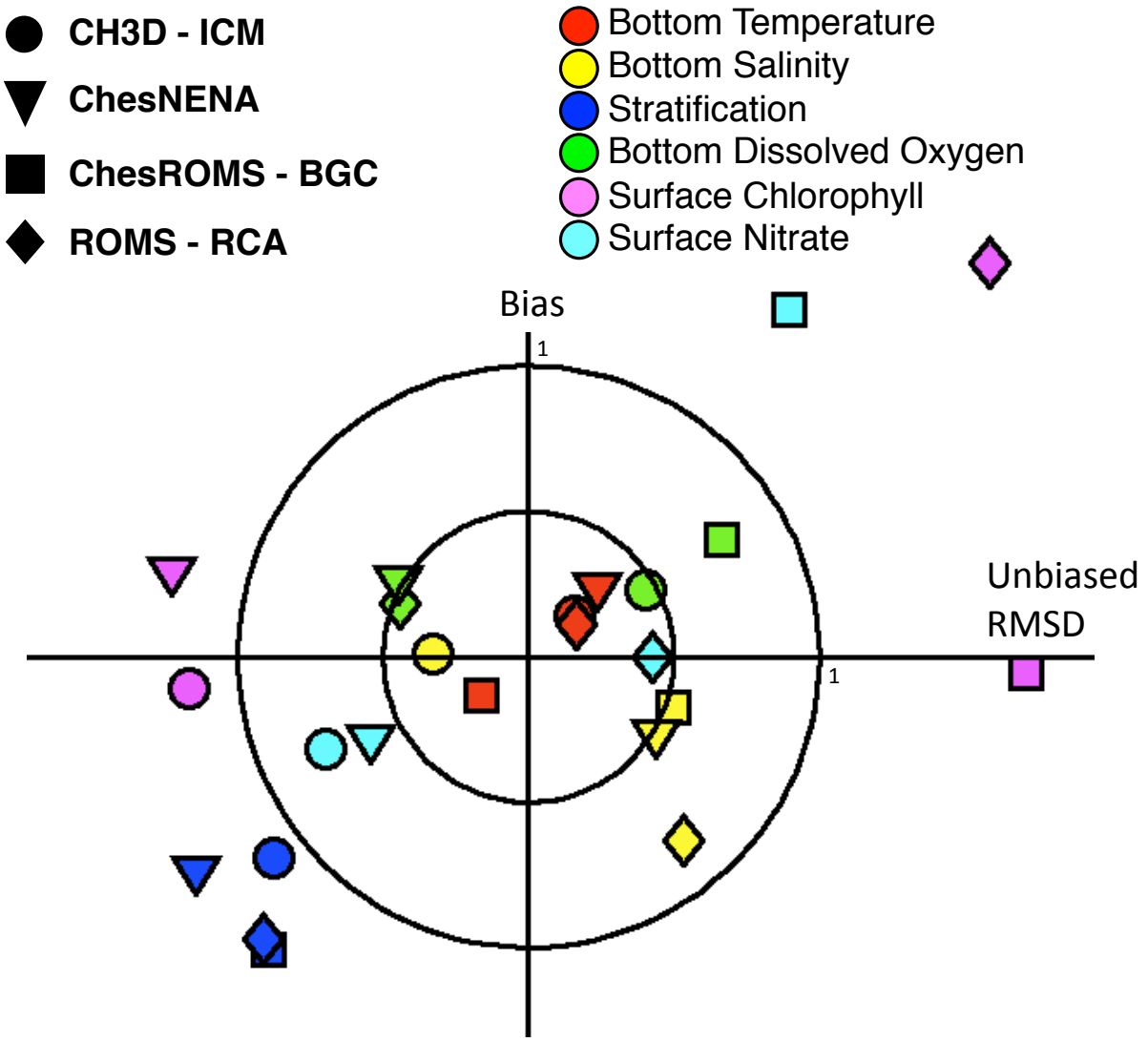
- How well do they reproduce the mean and seasonal variability of:
  - temperature, salinity, stratification, dissolved oxygen (DO), chlorophyll-a, and nitrate

Compare simulations to observations at 10 main stem stations for ~16 cruises in 2004 and 2005



Model Skill Assessment via Target Diagrams





Overall skill of all four models (temporal + spatial variability):

- are **highest** in terms of **Temperature**
- are **similar** to each other in terms of **T, S, stratification** and **DO**
- are **different** in terms of **chlorophyll** and **nitrate**

Model Comparisons via Chesapeake Testbed

- Regardless of complexity, models achieve similar skill scores in terms of seasonal variability of T, S, stratification and oxygen

- All models reproduce DO better than variables that are typically thought to be primary influences on DO (stratification, chlorophyll, nitrate)
  - This is because seasonal DO variability is sensitive to T (solubility effect), and the models reproduce T very well
  - Modeled DO simulations may be very sensitive to any future increases in Bay temperature

→ Oxygen forecasting is possible with simple biological formulation

Estuarine Hypoxia Goal

Compare multiple models within the Estuarine Hypoxia Testbed in order to improve existing:

1. **CBOFS short-term forecasting:** by incorporating new oxygen and physical model enhancements into the existing operational NOAA CO-OPS Chesapeake Bay Operational Forecast System (CBOFS) for evaluation during their next update

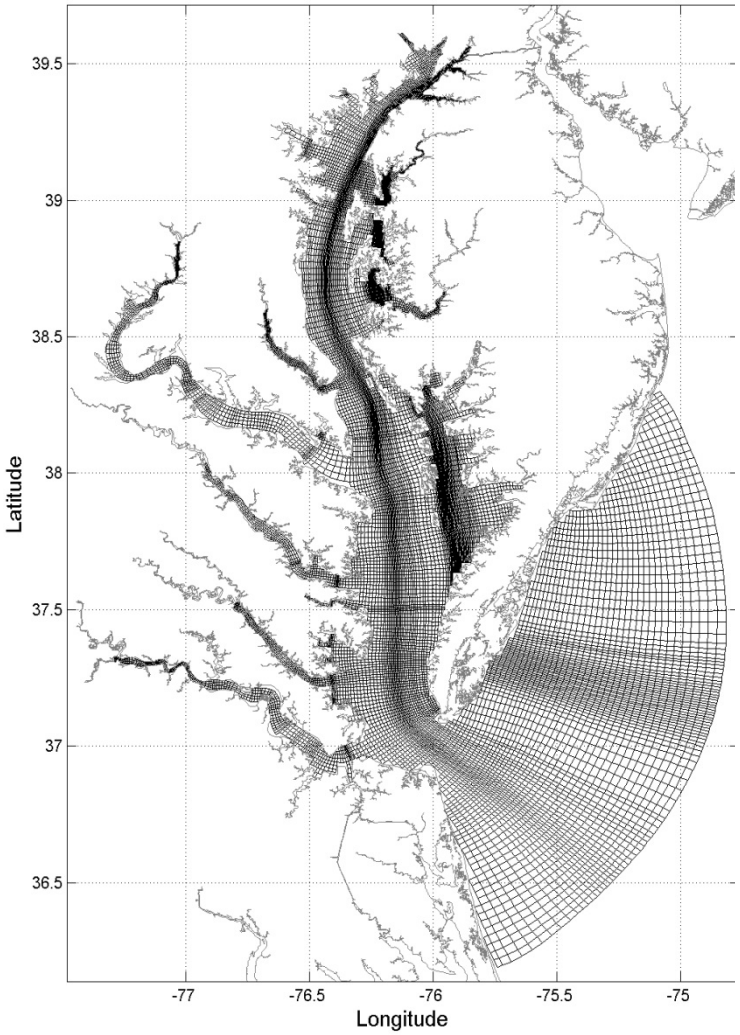
2. **CBEPS short-term forecasting:** by developing a 24/7 operational capacity for nowcasting/forecasting of oxygen/hypoxic volume as part of CBEPS at the NOAA CBPO and UMCES

3. **CBP scenario-based forecasting:** Apply the official CBP nutrient reduction strategies to COMT models to determine whether they perform similarly to the regulatory CBP model in terms of predicting the effect of reduced nutrients on hypoxia

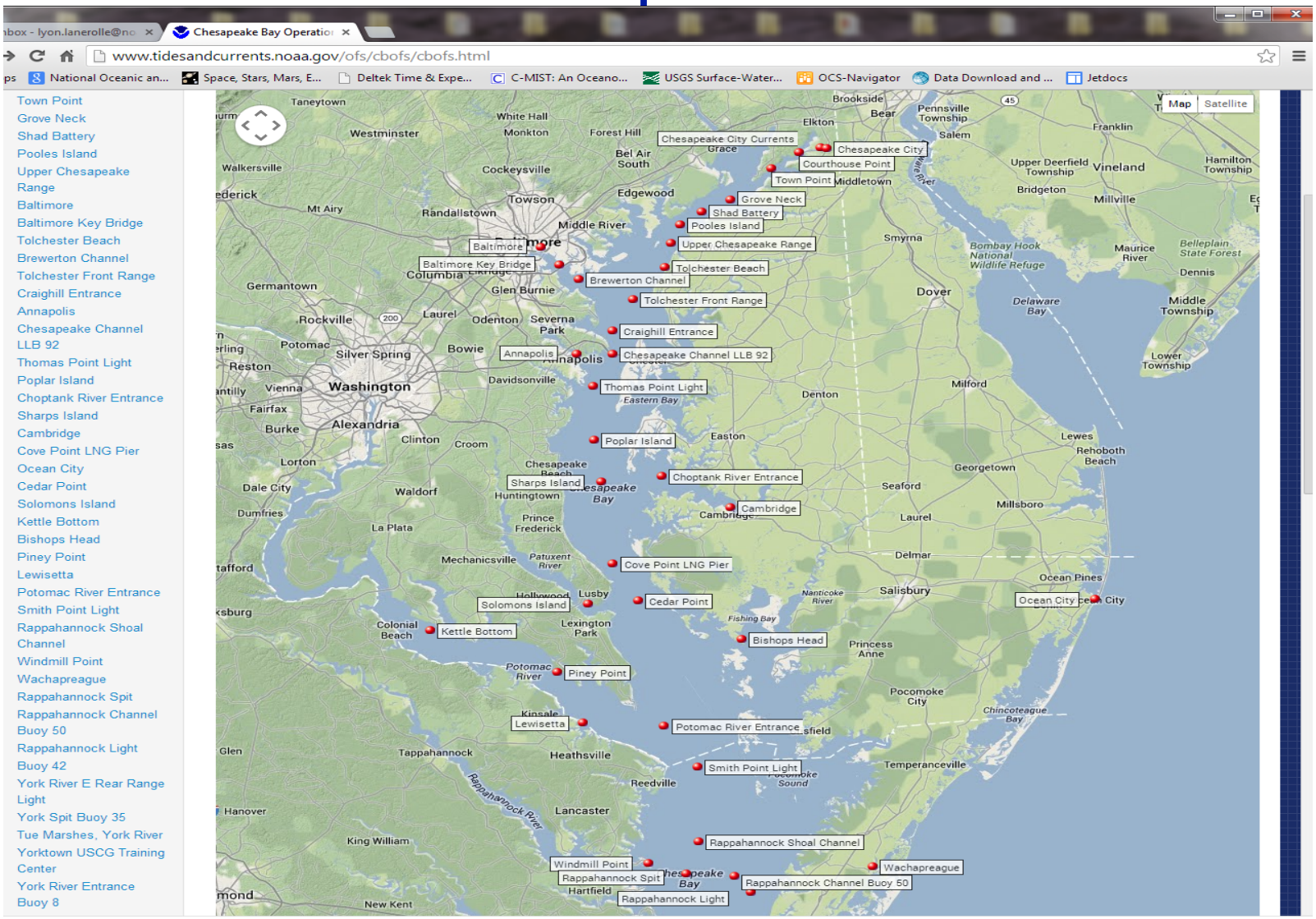
CBOFS

- CBOFS based on Regional Ocean Modeling System (ROMS)
- Grid generated in segments and pasted seamlessly using Delft3D-RGFGRID generator
- Bathymetry: NOS soundings cut-off at 2m depth
- Init Conds: NOAA T, S climatology for lower Bay and CBP profiles for upper Bay
- Rivers: discharge = USGS; T, S = CBP
- Outer Bdy Conds: T, S = NOAA climatology
- Outer Bdy Tides: tidal harmonic constituents for WL and barotropic currents from ADCIRC database
- No sediment, precipitation, wetting/drying or data assimilation

CBOFS Model Grid

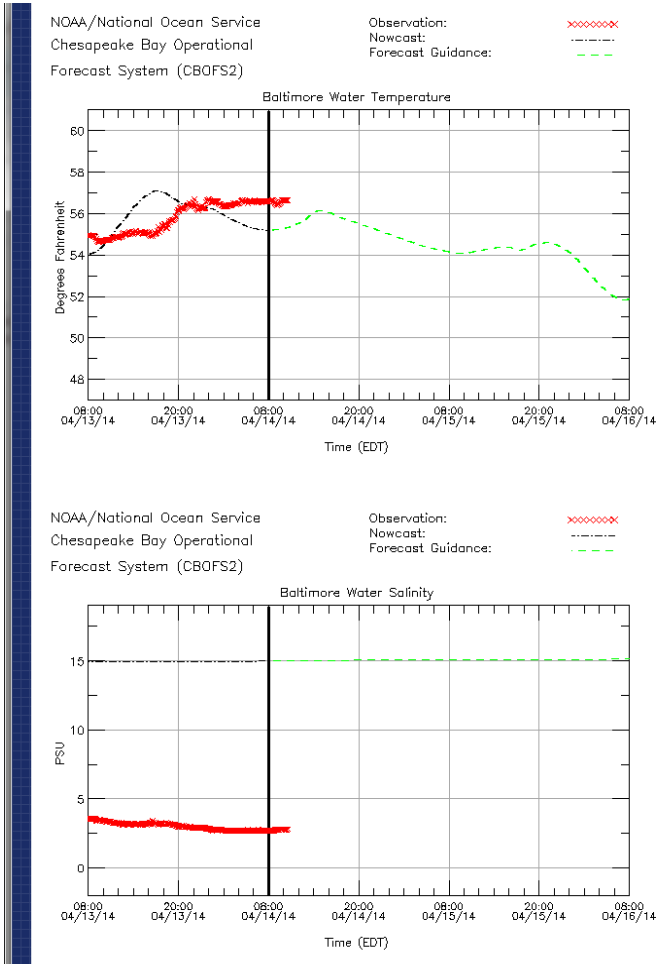


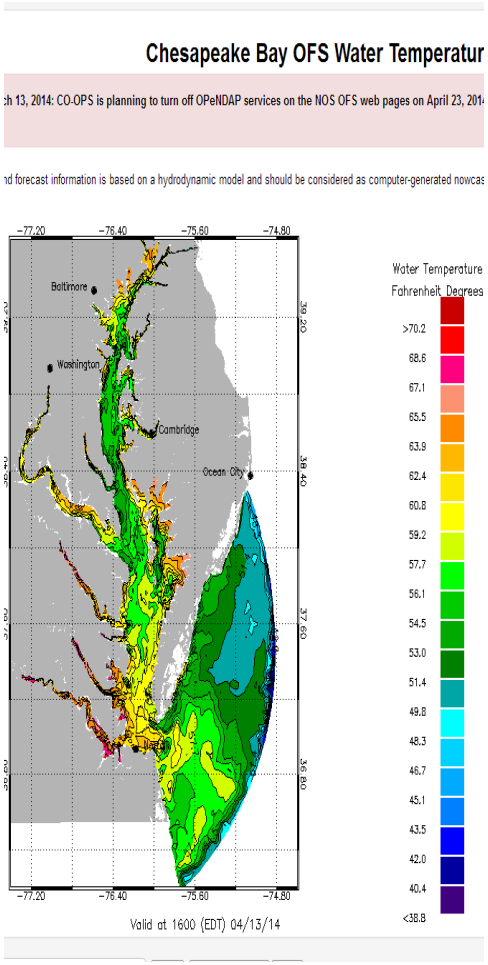
CBOFS – Model Output Archive Locations

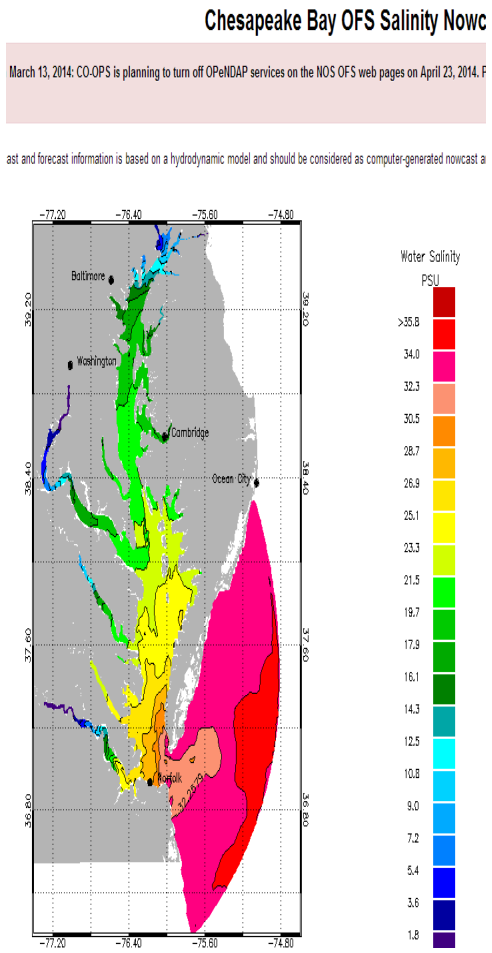


Archive water elevations, 3D currents, T and S at all of the above locations

CBOFS – Model Outputs







CBOFS

Goal 1: CBOFS short-term forecasting Incorporate new oxygen and physical model enhancements into the existing operational NOAA CO-OPS CBOFS for evaluation during their next update

Progress to Date:

- Staying in touch with NOS/CO-OPS on their salinity improvements
- COMT colleagues have recommended updated model options (advection scheme, TKE parameter, etc…)

Ongoing Work:

- Re-run CBOFS (2.5y) with new model options and updated code
- Compare multiple physical simulations; assess model skill relative to other COMT models
- Incorporate "best" constant biology DO model into CBOFS (Year 2?)
- Compare multiple DO simulations; assess model skill
- Finalize CBOFS code and have it ready for NOS/CO-OPS next update

Estuarine Hypoxia Goal

Compare multiple models within the Estuarine Hypoxia Testbed in order to improve existing:

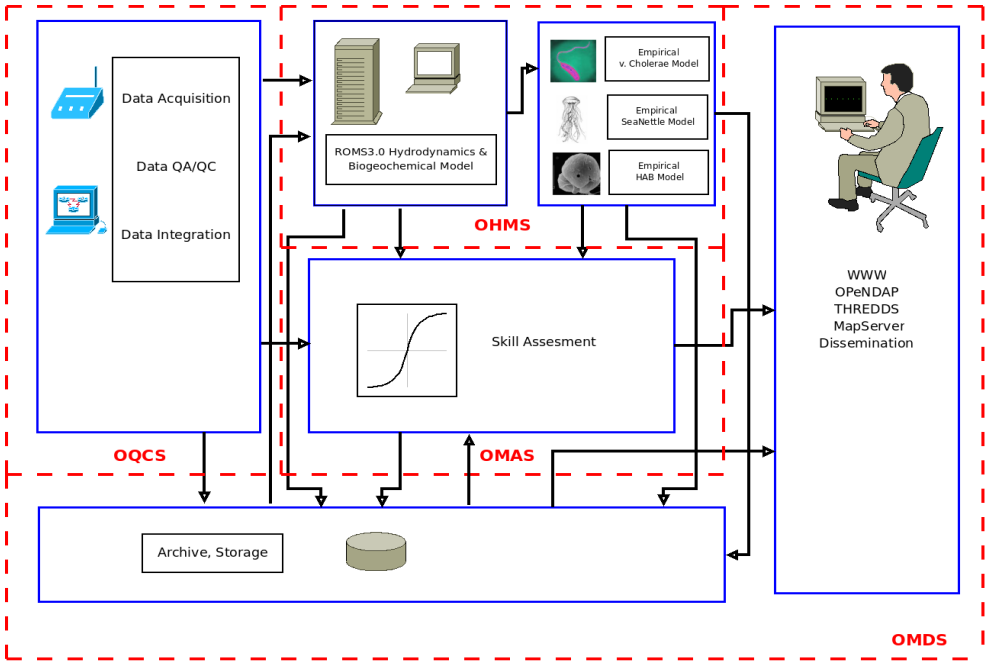
1. **CBOFS short-term forecasting:** by incorporating new oxygen and physical model enhancements into the existing operational NOAA CO-OPS Chesapeake Bay Operational Forecast System (CBOFS) for evaluation during their next update

2. **CBEPS short-term forecasting:** by developing a 24/7 predictive capacity for nowcasting/forecasting of oxygen/hypoxic volume as part of CBEPS at the NOAA CBPO and UMCES

3. **CBP scenario-based forecasting:** Apply the official CBP nutrient reduction strategies to COMT models to determine whether they perform similarly to the regulatory CBP model in terms of predicting the effect of reduced nutrients on hypoxia

Chesapeake Bay Ecological Prediction System (CBEPS) and Model Framework

- Coupled hydrodynamic/biogeochemical model (ChesROMS) running "operationally" at UMCES (formally supported by NOAA/NCBO)
- Nowcasts = real time USGS river discharge; Forecasts = assume river flows persist for 3 days
- Atmospheric forcing for 3-day forecasts from the North American Meteorological Model
- Simple seasonal climatologies/flow for biogeochemical boundary conditions
- Baywide nowcasts & 3 day forecasts of T and S are generated daily and posted
- Baywide ecological nowcasts & 3 day forecasts of Sea Nettles and Vibrio are generated daily, based on T, S logistical regression models (Vibrio not posted)

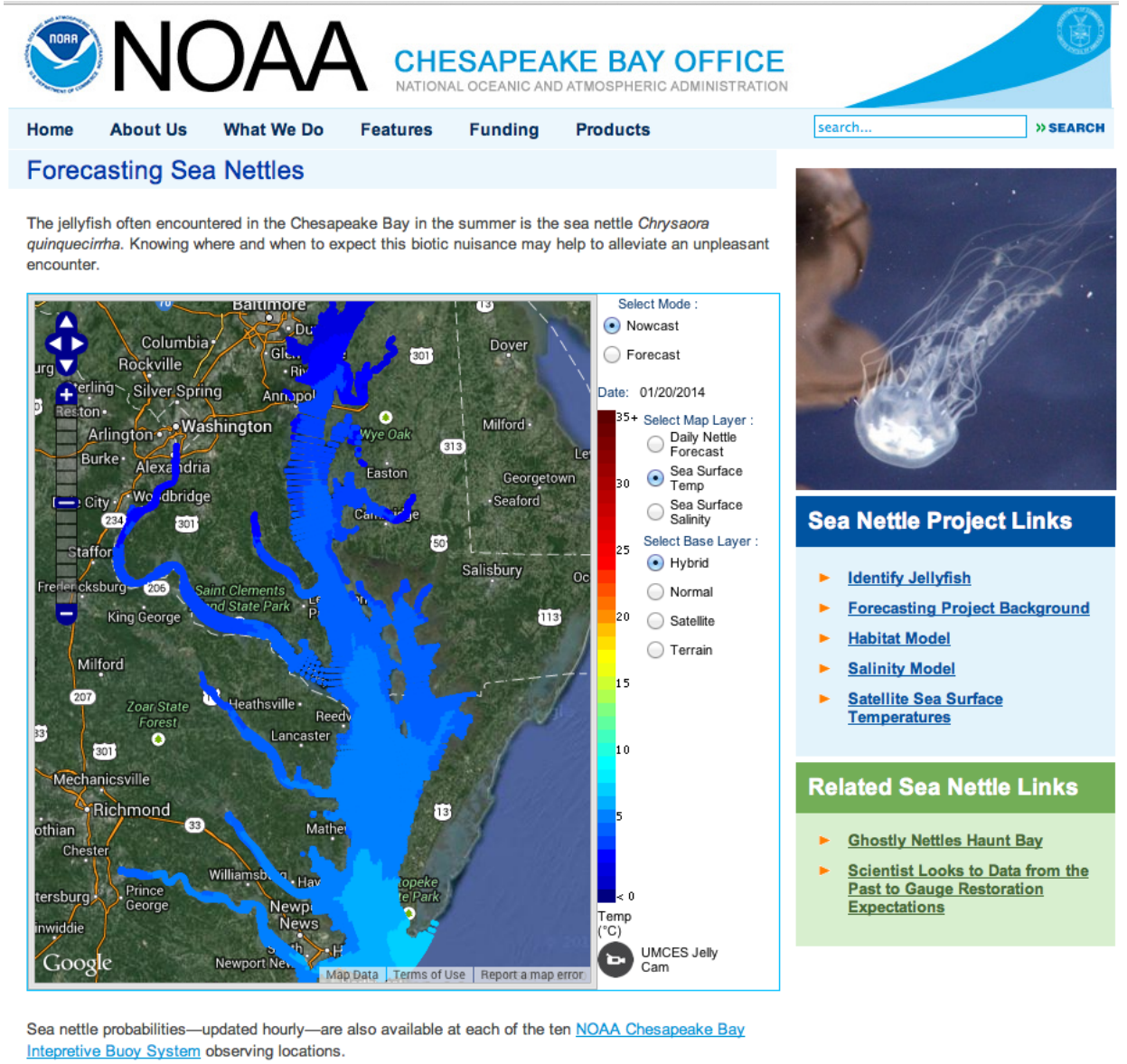


CBEPS Nowcasting/Forecasting Sea Nettles:

http://chesapeakebay.noaa.gov/forecasting-sea-nettles

- Maps generated daily and posted on website
- Nowcasts and 3-day forecasts
- **Sea Surface Temperature**

20 Jan 2014

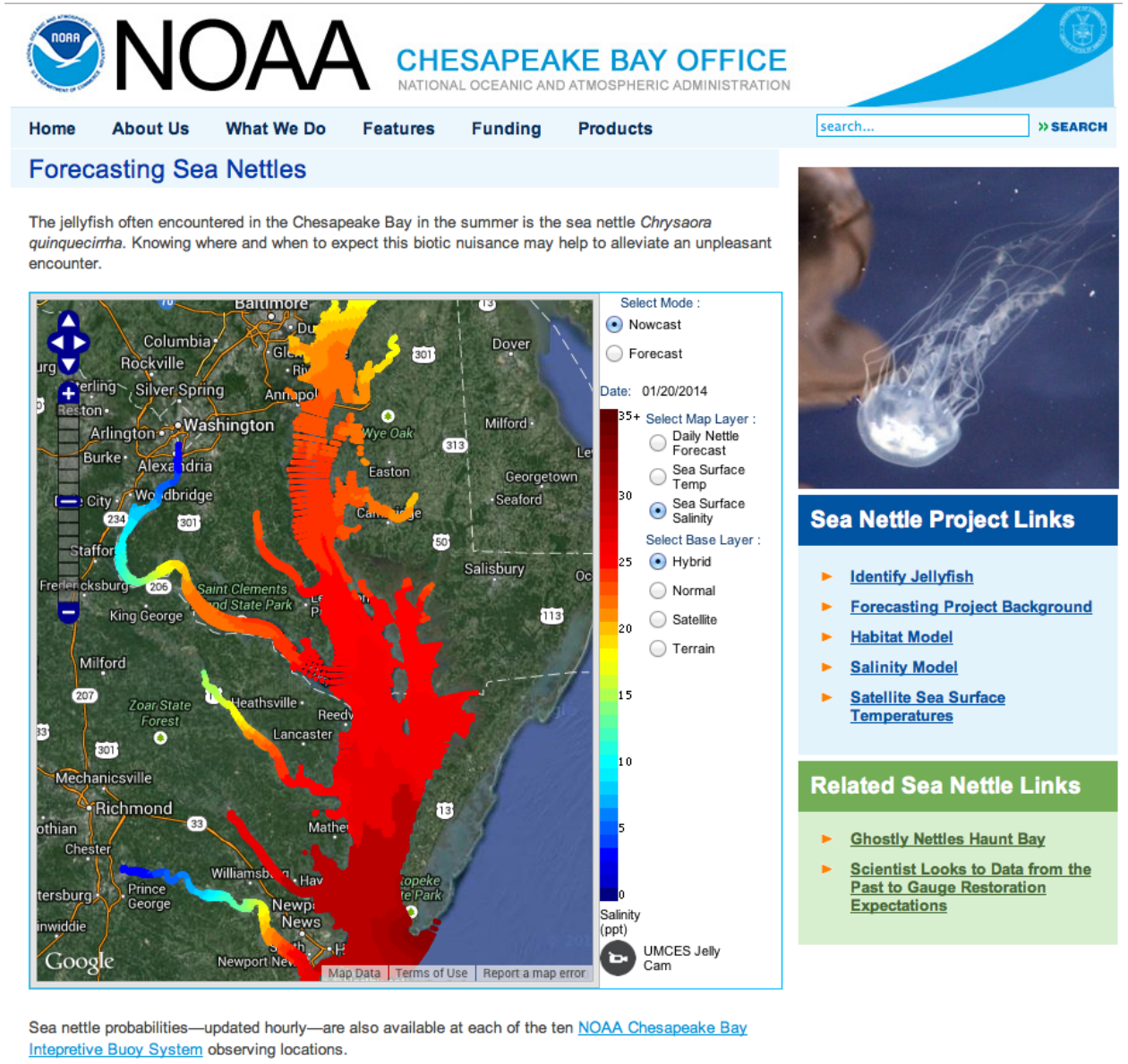


CBEPS Nowcasting/Forecasting Sea Nettles:

http://chesapeakebay.noaa.gov/forecasting-sea-nettles

- Maps generated daily and posted on website
- Nowcasts and 3-day forecasts
- Sea Surface Temperature
- **Sea Surface Salinity**

20 Jan 2014

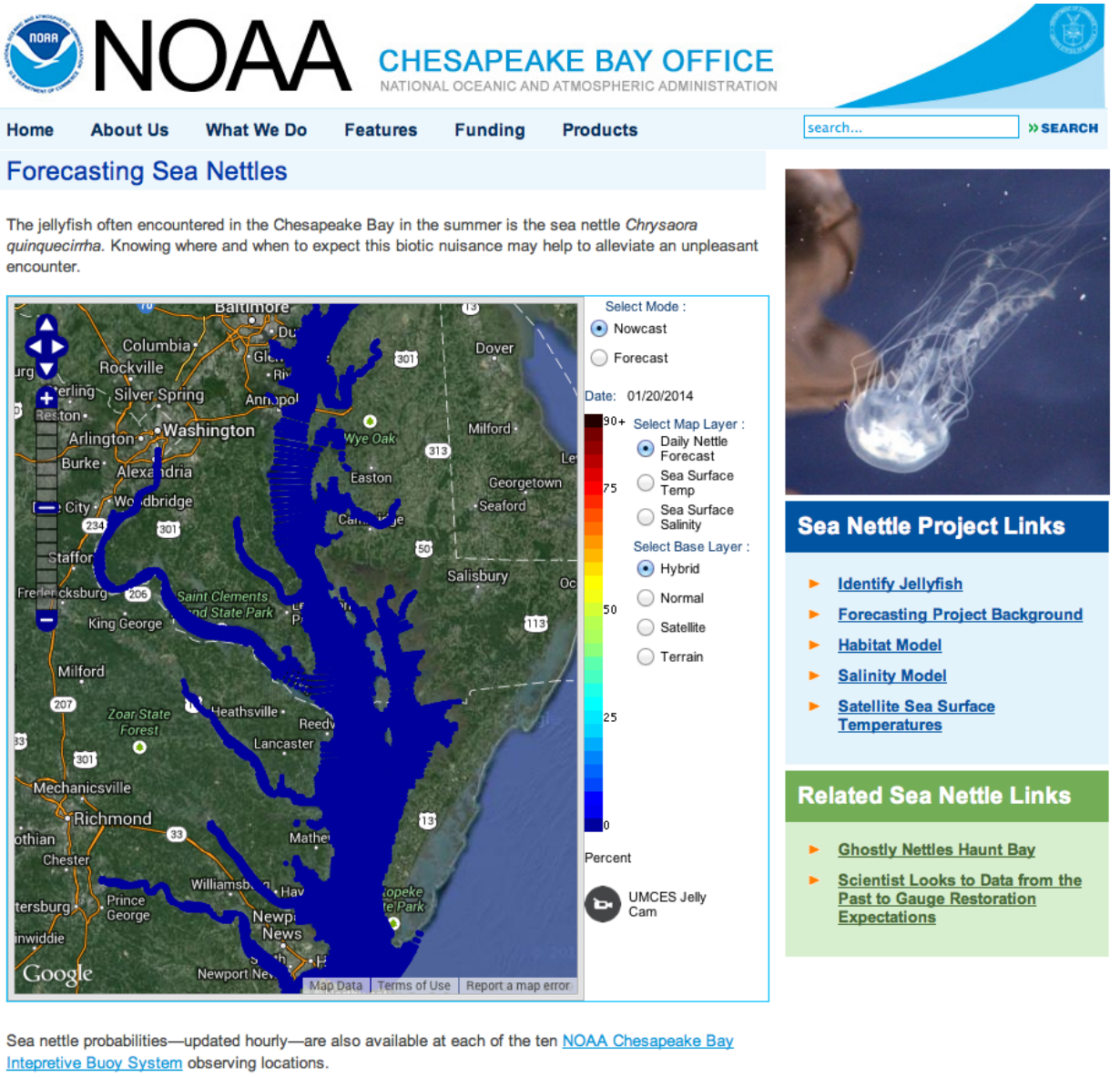


CBEPS Nowcasting/Forecasting Sea Nettles:

http://chesapeakebay.noaa.gov/forecasting-sea-nettles

- Maps generated daily and posted on website
- Nowcasts and 3-day forecasts
- Sea Surface Temperature
- Sea Surface Salinity
- **Sea Nettles**

20 Jan 2014

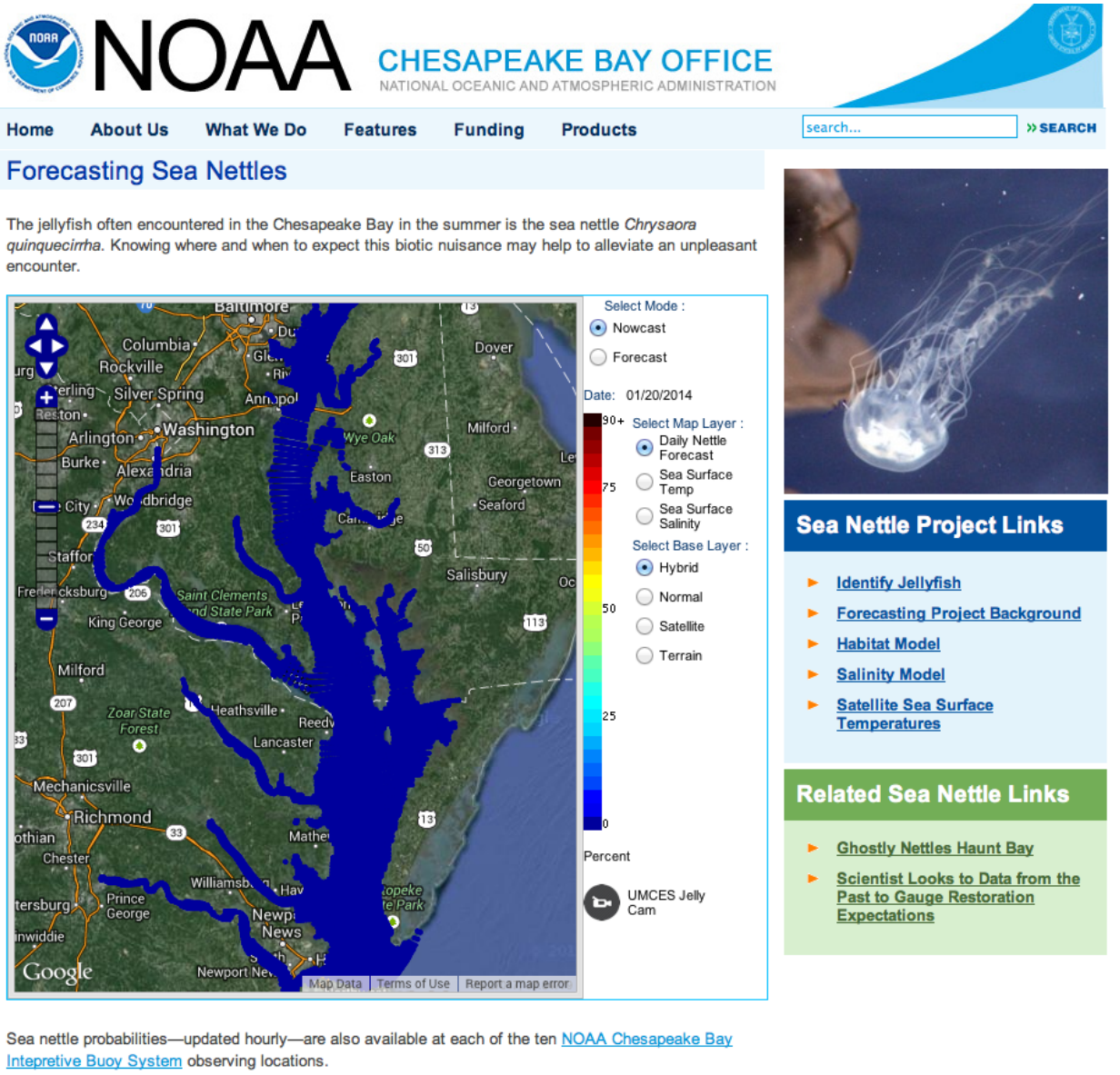


CBEPS Nowcasting/Forecasting Sea Nettles:

http://chesapeakebay.noaa.gov/forecasting-sea-nettles

- Maps generated daily and posted on website
- Nowcasts and 3-day forecasts
- Sea Surface Temperature
- Sea Surface Salinity
- Sea Nettles
- **Vibrio (not posted)**

20 Jan 2014



Chesapeake Bay Ecological Prediction System (CBEPS)

Goal 2: CBEPS short-term forecasting Develop a 24/7 predictive capacity for nowcasting/forecasting of oxygen/hypoxic volume at NOAA CBPO & UMCES

Progress to Date:

•Currently running 3 day forecasts "operationally" at UMCES for Chesapeake-biogeochemistry (based on "old" version of ChesROMS)
•Developed "sea nettles" forecast – transitioned to a 24/7 demonstrative product at NOAA through CBOFS (Success!) – still need to carry out skill assessment
• Other organisms act similarly, e.g. Vibrio

Ongoing Work:

- Add simple DO formulation to list of variables forecasted
- Update ChesROMS physics
- Ultimately merge features of two ROMS-BGC models: ChesNENA and ChesROMS

Estuarine Hypoxia Goal

Compare multiple models within the Estuarine Hypoxia Testbed in order to improve existing:

1. **CBOFS short-term forecasting:** by incorporating new oxygen and physical model enhancements into the existing operational NOAA CO-OPS Chesapeake Bay Operational Forecast System (CBOFS) for evaluation during their next update

2. **CBEPS short-term forecasting:** by developing a 24/7 operational capacity for nowcasting/forecasting of oxygen/hypoxic volume as part of CBEPS at the NOAA CBPO and UMCES

3. **CBP scenario-based forecasting:** Apply the official CBP nutrient reduction strategies to COMT ROMS models to determine whether they perform similarly to the regulatory CBP model in terms of predicting the effect of reduced nutrients on hypoxia (Year 2)

CBP Scenario-based Forecasting

Progress to Date:

- Developed methodology to use an alternate hydrodynamic+biogeochemical model to reproduce Water Quality Standards for CBP
- EPA Chesapeake Bay Program folks are enthusiastic about our proposed effort to assess confidence/uncertainties in their regulatory model

Future Work:

•Run alternate model(s) with CBP's nutrient reduction scenarios.
•Apply CBP protocol to both sets of model scenarios
•For each model, identify when/where Bay will meet required "water quality standards"
•How do the model results diverge? Where/when are the greatest uncertainties in the TMDLs computed from these model results?

The Estuarine Hypoxia COMT model skill comparisons are improving:

→ NOAA CBOFS nowcasts/forecasts

→ UMCES CBEPS nowcasts/forecasts

→ CBP scenario-based forecasts