Results of the US IOOS Testbed for Comparison of Results (i) Hydrodynamics: Temporal variability of stratification at 40 stations Hydrodynamic and Hypoxia Models of Chesapeake Bay Carl Friedrichs (VIMS) and the Estuarine Hypoxia Team Model behavior for stratification is similar in terms of temporal **Federal partners** variation of error at individual David Green (NOAA-NWS) – Transition to operations at NWS • Lyon Lanerole, Rich Patchen, Frank Aikman (NOAA-CSDL) – Transition to operations at CSDL; CBOFS2 • Lewis Linker (EPA), Carl Cerco (USACE) – Transition to operations at EPA; CH3D, CE-ICM Doug Wilson (NOAA-NCBO) – Integration w/observing systems at NCBO/IOOS CBOFS2 Non-federal partners • Marjorie Friedrichs, Aaron Bever (VIMS) – Metric development and model skill assessment • Ming Li, Yun Li (UMCES) – UMCES-ROMS hydrodynamic model Wen Long, Raleigh Hood (UMCES) – ChesROMS with NPZD water quality model • Scott Peckham (UC-Boulder) – Running multiple ROMS models on a single HPC cluster Malcolm Scully (ODU) – ChesROMS with 1 term oxygen respiration model • Kevin Sellner (CRC) – Academic-agency liason; facilitator for model comparison **UMCES-ROMS** • Jian Shen (VIMS) – SELFE, FVCOM, EFDC models • John Wilkin, Julia Levin (Rutgers) – ROMS-Espresso + 7 other MAB hydrodynamic models (from A. Bever, M. Friedrichs) Methods (i) Models: 5 Hydrodynamic Models (so far) Results (i) Hydrodynamics (cont.): Sensitivity of stratification at pycnocline (1) CH3D Stratification L. Linker/C. Cerco, EPA/USACE CBP) (from A. Bever, M. Friedrichs) ChesROMS + 1-Term ChesROMS + Depth Dep. CH3D EFDC **ubRMSD** ChesROMS ChesROMS CF CBOFS2 CF CH3D, EFDC UMCES ROMS HR ChesROMS + 1T 2005 Chesroms + Depth Dep. (3) ChesROMS Stratification at pycnocline is not sensitive to horizontal grid resolution or changes (R. Hood/W. Long, UMCES) in atmospheric forcing. (Stratification is still always underestimated) (5) CBOFS2 (& J. Wiggert/J. Xu, (L. Lanerolle, NOAA-CSDL) USM/NOAA-CSDL) Results (ii): Dissolved Oxygen Model Comparison Methods (i) Models (cont.): 5 Dissolved Oxygen Models (so far) Outer circle = error from simply bias [km³] (a) Bottom (b) Hypoxic using mean of all data ICM: CBP model; complex biology Volume Dissolved O₂ bgc: NPZD-type biogeochemical model Inner circle = error from ICM model 1eqn: Simple one equation respiration (includes SOD) 1term-DD: depth-dependent net respiration unbiased unbiased (not a function of x, y, temperature, nutrients...) **RMSD RMSD** 1term: Constant net respiration [mg/L] Methods (i) Models (cont.): 8 Multiple combinations (so far) • ICM EFDC-1eqn ICM o CH3D CBOFS2-1term o EFDC ChesROMS-1term 1egn, 1term average ChesROMS-bgc 1term, 1term+DD ChesROMS-1DD 1term, 1term+DD, bgc - Simple models reproduce dissolved oxygen (DO) and hypoxic volume about as well as more complex models. - All models reproduce DO better than they reproduce stratification. - A five-model average does better than any one model alone. (from A. Bever, M. Friedrichs) Methods (ii) observations: S and DO from Up to 40 CBP station locations Results (ii) Dissolved Oxygen: Top-to-Bottom ΔS and Bottom DO in Central Chesapeake Bay Top to Bottom Salinity Difference CB4.3 Data set for model skill assessment: ChesROMS-1term ~ 40 EPA Chesapeake Bay stations model Bottom DO CB4.3 Each sampled ~ 20 times in 2004 Temperature, Salinity, Map of Late July 2004 Dissolved Oxygen Observed Oxygen - All models reproduce DO better than they reproduce stratification. - So if stratification is not controlling DO, what is? (by M. Scully) (http://earthobservatory.nasa.gov/Features/ChesapeakeBay) Methods (iii) Skill Metrics: Target diagram Results (ii) (cont.): Effect of Physical Forcing on Dissolved Oxygen Total RMSD 2 = Bias 2 + unbiased RMSD 2 ChesROMS-1term model variability mean Freshwater river input Dimensionless version of constant plot normalizes by standard July wind year-round Hypoxic Volume in km³ deviation of observations Inside unit circle: model does better than mean of data **Base Case** y > 0: On unit circle: model-data misfit = variability in data overestimates **Unbiased RMSD** Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Bull's eye: Date in 2004 January wind year-round perfect model-data agreement Outside unit circle: model does worse than Seasonal changes in hypoxia are not a function of seasonal changes in freshwater. the mean of the data overestimates Instead, seasonal hypoxia may be largely due to seasonal changes in wind. variability (modified from M. Friedrichs) (by M. Scully) Results (i): Hydrodynamic Model Comparison SUMMARY & CONCLUSIONS (a) Bottom bias [°C] Water Depth (b) Bottom Temperature Inner circle in (a) & (b) = error - All models do very well hind-casting temperature. Available models generally have similar skill in terms of hydrodynamic quantities 30 - All do well hind-casting • All the models underestimate strength and variability of salinity stratification. bottom salinity with CH3D and EFDC doing best. -6 -4 🙋 0 /2 4 6 No significant improvement in hydrodynamic model skill due to refinements in: Background image: CBOFS2 model bathymetry http://tidesandcurrents.noaa.gov/images/cbofs2_bathy.png - Horizontal/vertical resolution, atmospheric forcing, freshwater input, ocean forcing. CH3D 20 EFDC - Stratification is a challenge • In terms of DO/hypoxia, simple constant net respiration rate models reproduce ChesROMS for all the models. seasonal cycle about as well as complex models. • UMCES ROMS CBOFS2 - All underestimate bias [psu/m] Models reproduce the seasonal DO/hypoxia better than seasonal stratification. (c) Stratification 1.5 strength and variability of Outer circle in each case = error (d) Depth of stratification with CH3D at pycnocline from simply using mean of all data and EFDC doing slightly • Seasonal cycle in DO/hypoxia is due more to wind speed and direction than to seasonal cycle in freshwater input, stratification, nutrient input or respiration. VIRGINIA INSTITUTE OF MARINE SCIENCE unbiased - CH3D and ChesROMS do **RMSD** - Note: This does **not** mean than inter-annual variation in nutrient input/respiration is unimportant. slightly better than others [psu/m] for pycnocline depth, with -1.5\ -1 **-**0.5 0.5 Averaging output from multiple models provides better hypoxia hindcast than CH3D too deep, and the others too shallow. relying on any individual model alone. - All underestimate variability of pycnocline (11) (from A. Bever, M. Friedrichs)