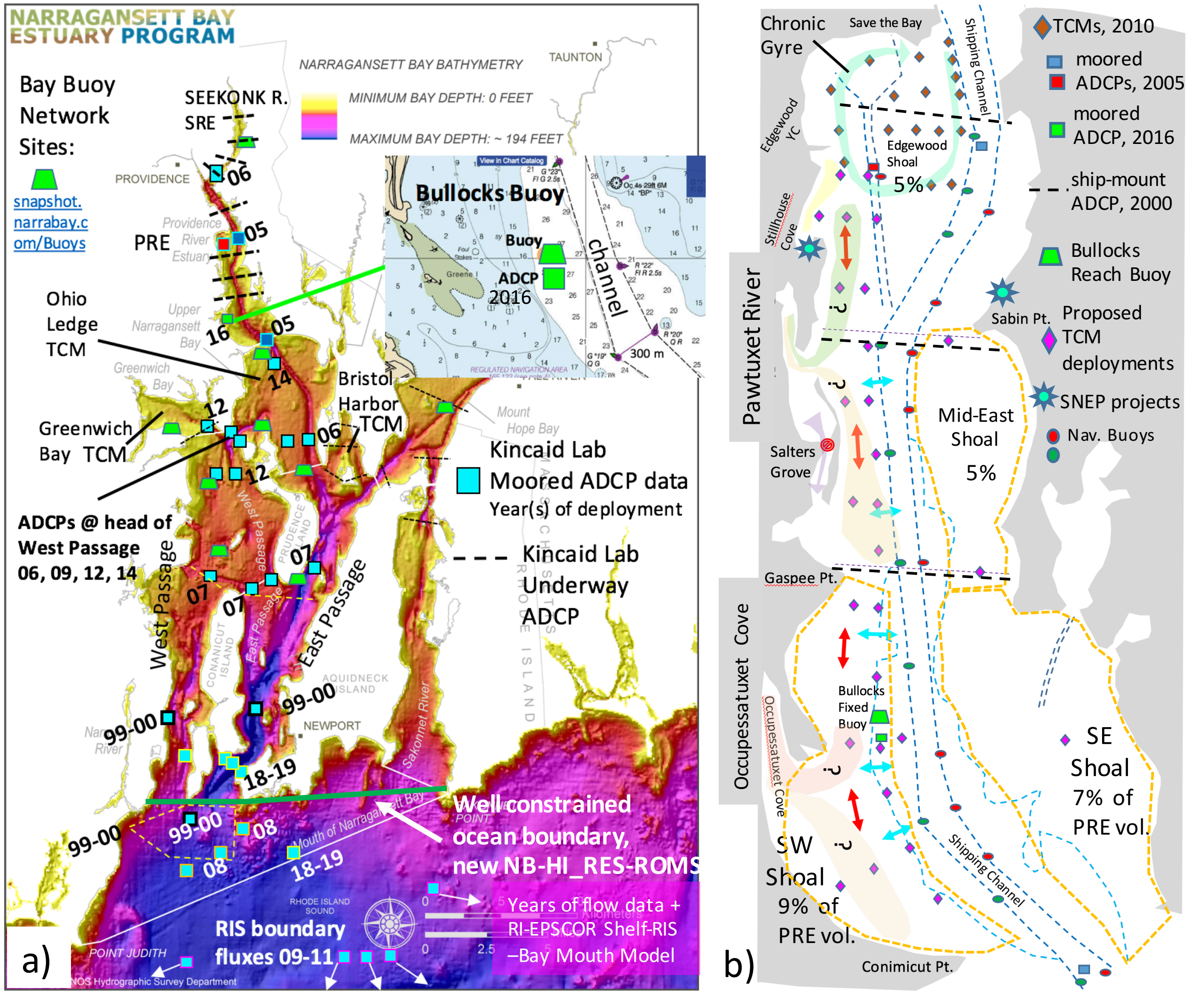
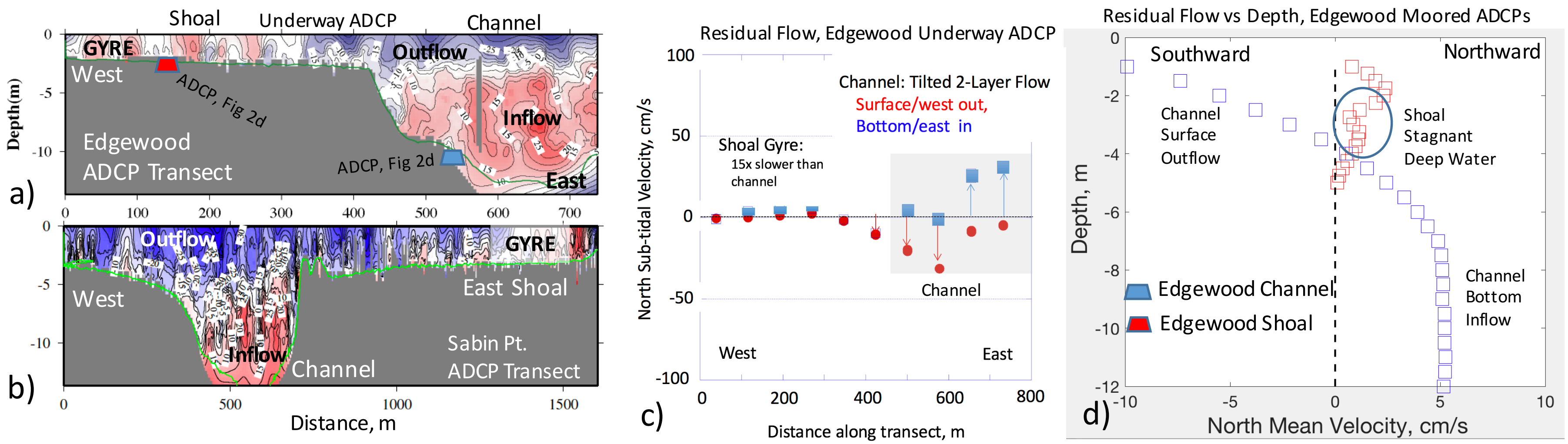


Figure 1. The proposed project builds from years of circulation and hydrographic (T/S) data in RI waters. a) Map of data locations for ADCP deployments providing spatially and temporally detailed data (moored vs underway ADCP). Networks of 15-25 tilt current meters (TCMs) provide exceptional spatial & temporal data (labeled). Proposed project utilizes 2018-2019 ADCP data at Bay mouth, with EPSCOR-OSOM shelf-Bay model to inform our new higher resolution ROMS circulation-biochemical-ecosystem models (NB-HI_RES-ROMS). Flow data from every region of the Bay helps to inform/validate all modeling activity. b) Close-up map of Providence River estuary (PRE), with existing and proposed physics data. Proposed project focuses on improving data and models of interactions between impaired PRE shoals and shipping channel. Improved physics models to be applied to tracking all freshwater plumes, specifically from Pawtuxet River & Occupessatuxet Cove (potential paths shown as shaded fields). Motivation for improved ROMS from co-located Bullocks buoy and moored ADCP (inset in (a)) highlighting data-model inaccuracies. New TCM data on shoal-channel physics (purple diamonds) and refined ROMS grid provides improved modeling tool for eco-models and supporting/assessing environmental management strategies. Thanks to NBEP for use of base map in Fig. 1a.



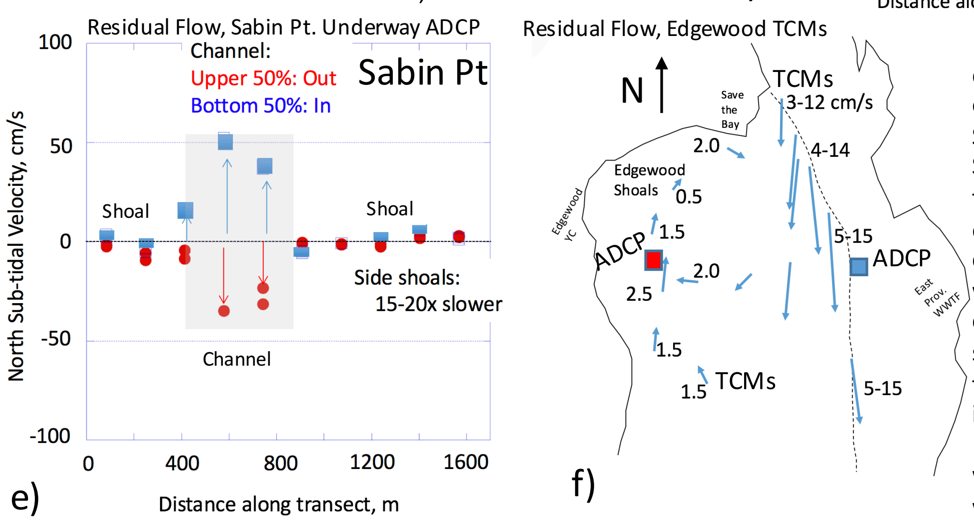
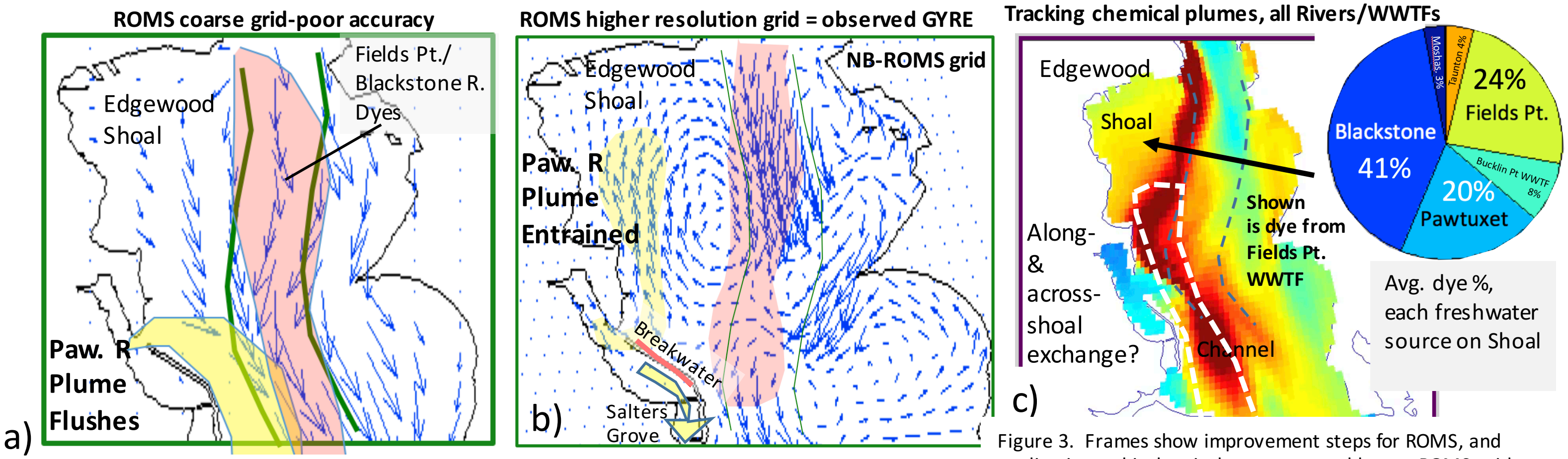


Figure 2. A range of data sets/types show the severe hydrodynamic differences between dredged channel and shallow shoal regions. a) Example of ADCP transect data (northward velocity, east-west distance vs. depth) from Summer 2000. Data are from late ebb. (red=inflow, blue=outflow). b) Similar contour but for Sabin Pt. transect (see Fig. 1b). Robust, repeatable features are strong outflow at surface/west side of channel and inflow though deeper/east side of channel. Weakly circulating gyres are features of shoals. c) Data from 16 hour ADCP surveys are used to calculate residual (sub-tidal) water flow (red= avg. surface, blue= avg. bottom) across Edgewood shoal and channel. d) Mean northward velocity profile from 2005 ADCPs (Blue=west side of channel; red=shoal, see Fig 1,2a). e) Similar to (c), but residual flow for the Sabin Pt. underway ADCP data. f) TCMs deployed on Edgewood Shoal in 2010 reveal fine spatial-temporal details in tidal and residual circulation. Here mean flow vectors show strong down-bay flow at the channel edge, and weak flow on the shoal. TCM data show oscillations between periods of shoal water retention and rapid flushing events. New data will map flushing patterns on other, larger shoals within the Prov. River estuary.



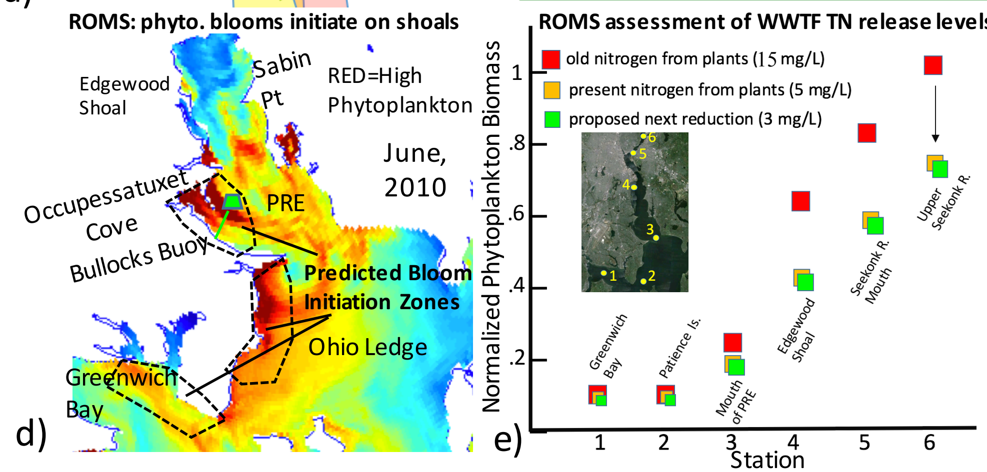
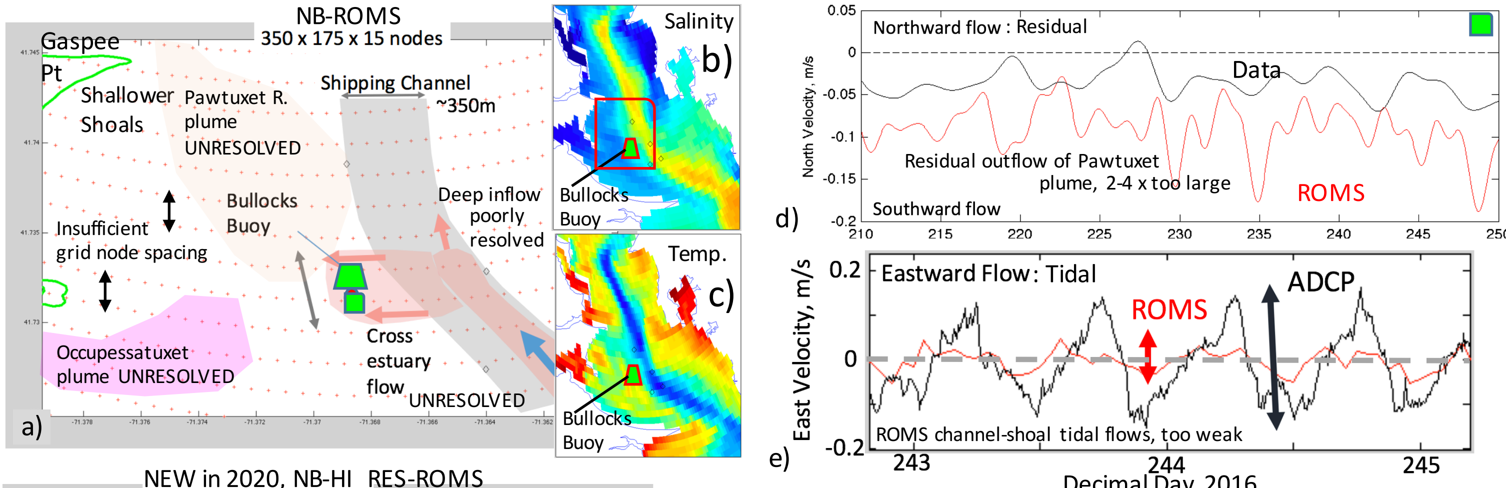


Figure 3. Frames show improvement steps for ROMS, and application to biochemical transport problems. ROMS grid resolution (spacing of nodes) controls solution accuracy. a) Early, coarse ROMS doesn't produce Edgewood gyre, predicts rapid flushing of shoal. b) Higher resolution NB-ROMS simulates gyre, matches TCM data and predicts Pawtuxet R. entrainment in gyre. c) Chemical dyes in NB-ROMS tag each river and WWTF, revealing which sources are retained in each sub-region of Bay (Red= Fields Pt. WWTF dye). Pie diagram inset, percentages of water sources on Edgewood Shoals, 6/2010. Pawtuxet R. is significant source. d) NB-ROMS models also used to simulate NPZD processes. Repeatable result is phytoplankton bloom initiation hotspots (dashed regions) (from summer,2010 simulations). e) NB-ROMS also used to assess WWTF-TNR strategies. Plot shows integrated phytoplankton biomass (M/m³) for different WWTF-TN permit levels. Values, scaled to largest blooms, using pre-2004 TN levels. WWTF TN effluent reductions from 15 to 5 mg/L show consistently large improvements (for all conditions tested).



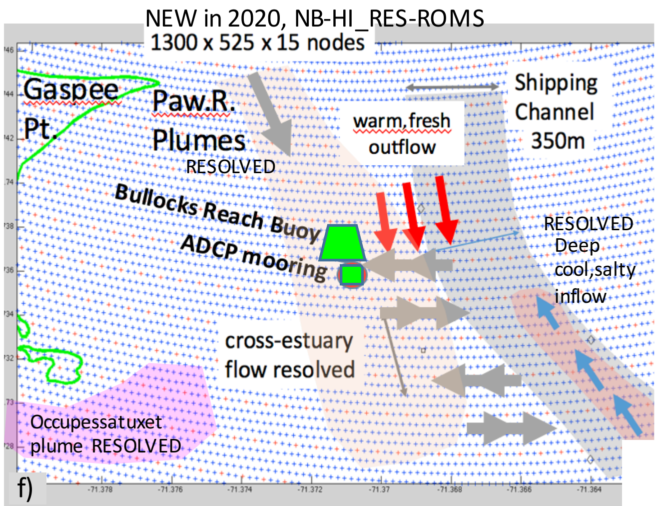


Figure 4. a) Mapview of lower Providence River showing key region of shoal-channel interactions (south of Gaspee Pt) that motivated the proposed project. Based on suggestions from RI-DEM, work was done to understand why the NB-ROMS model did poorly at the Bullocks Reach buoy site (green symbol). A moored ADCP and numerous simulations (insets show modeled (b) salinity (S) and (c) temp. (T)) reveal issues with insufficient grid resolution (red dots) for resolving key processes, like cross-estuary exchange. Models predict bottom water at buoy that is too cool/fresh. d) Plots of northward residual flow for model (red) and ADCP data (black) show ROMS significantly overestimates along shoal flushing. e) Alternatively, simulated eastward, cross estuary tidal flows in NB-ROMS are smaller than ADCP data. f) The proposed project will take advantage of Spring, 2020 improvements in ROMS grid resolution (NB-HI_RES-ROMS). Similar mapview as (a), but showing improved grid node spacing reflected at Bullocks Reach buoy region (blue dots = new grid; red dots= old, NB-ROMS grid). The new grid enables better simulation of channel inflows/outflows (seen in ADCP data, Fig. 2a,b) and both shoal-shoal and shoal-channel exchange physics. This translates to more accurate models of dispersion/retention of biochemical plumes from key western and northern sources (shown as shaded regions) and our ROMS coupled ecosystem simulations. Models must still be quantitatively compared (validated) with physics data. Proposed TCM data (Fig. 1b) provides this essential information for SW and SE shoal regions that remain completely unmapped at this point .