Modeling the dynamics of small-scale river and creek plumes in tidal waters

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The fate of discharges from small rivers and mountainous streams are little studied relative to the dynamics of large river plumes. Flows from small watersheds are episodic, forming transient low-salinity surface plumes that vary tidally due to interaction of outflow inertia with buoyancy and ambient tidal currents. An implementation of the Regional Ocean Modeling System (ROMS v3.0), a three-dimensional, free-surface, terrain-following numerical model, is applied to small river outflows (≤ 10 m^3 s^{-1}) entering a tidal ocean, where they form small plumes of scale $\sim 10^3$ m or smaller. Analysis of the momentum balance points to three distinct zones: (i) an inertia-driven near field, where advection, pressure gradient, and vertical stress divergence control the plume dynamics, (ii) a buoyancy-driven midfield, where pressure gradient, lateral stress divergence, and rotational accelerations are dominant, and (iii) an advective far field, where local accelerations induced by ambient tidal currents determine the fate of the river/estuarine discharge. The response of these small tidal plumes to different buoyancy forcing and outflow rate is explored. With increasing buoyancy, plumes change from narrow/elongated, bottom-attached flows to radially expanding, surface-layer flows. Weak outflow promotes stratification within the plume layer, and with stronger outflow, the plume layer becomes thinner and well-mixed. When compared with prototypical large-river plumes in which Coriolis effects are important, (i) in these small plumes, there is no bulge and no coastal buoyancy current, that is, shore contact is mostly absent, and (ii) the plume is strongly influenced by ambient tidal currents, forming a tidal plume that is deflected upcoast/downcoast from the river mouth.