River bulge spreading, numerical and laboratory simulations

Edith Soosaar[1], Robert D. Hetland[2], Alexander Horner-Devine[3], Margaret E. Avener [3], Urmas Raudsepp[1]

1) MSI TUT, 2) Texas A&M, 3) University of Washington

Introduction

- Reproduce buoyant water entering a coastal sea at laboratory scales of O[1 cm] .
- Three-dimensional hydrodynamic model Regional Ocean Modeling System (ROMS).
- Laboratory data from a rotating circular basin experiment.
- The numerical domain is a rectangular basin with three open boundaries and a straight inflow channel for freshwater discharge.
- Altogether 11 pairs of laboratory-numerical simulation runs and three additional model runs are analyzed.
- Rotation rate, ambient salinity and inflow rate- including oscillatory inflow as a proxy for tides, is varied.

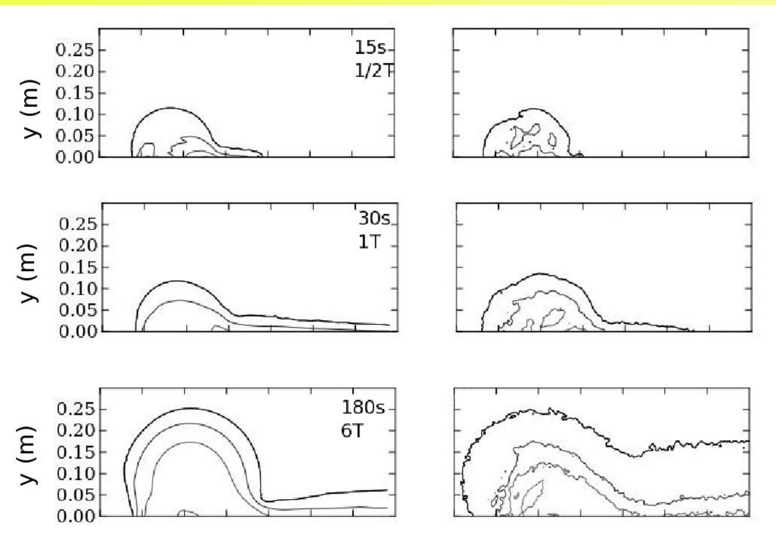
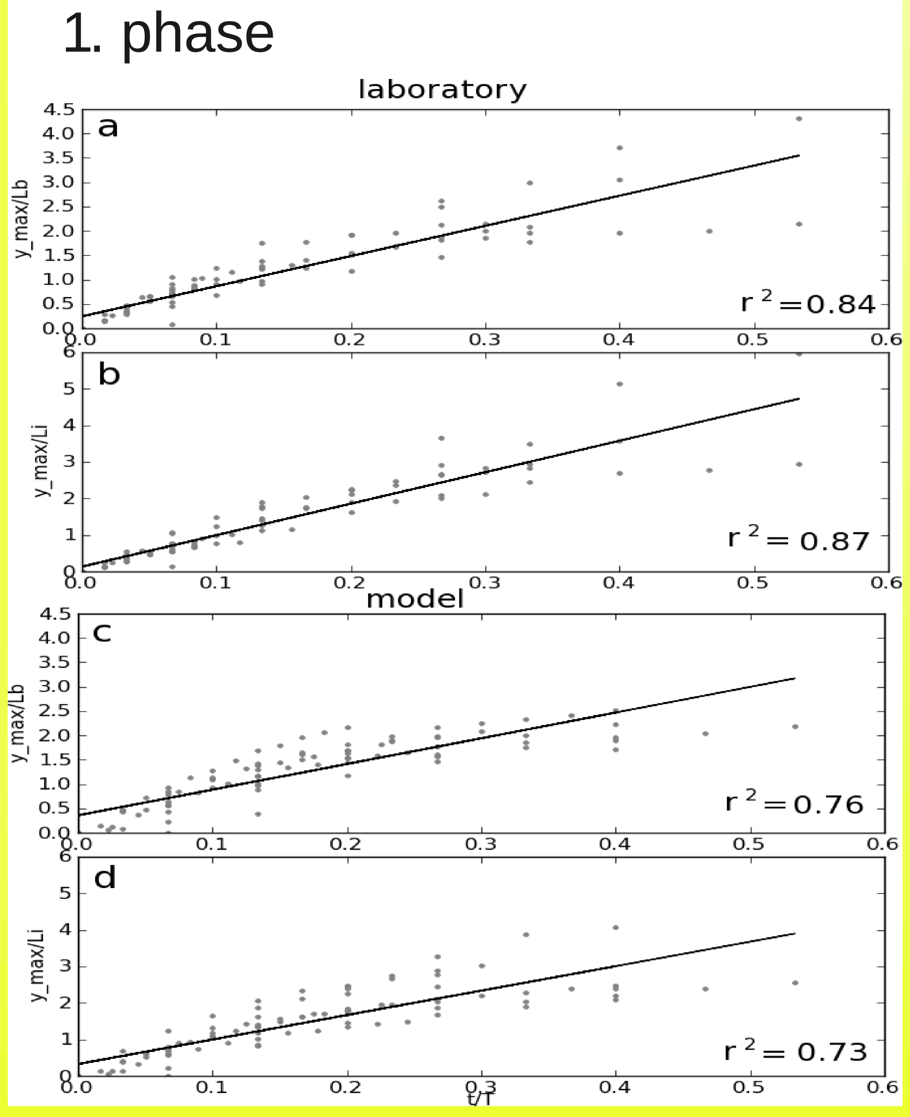


Figure (up): Plume time evolution. Run nr 1 for model (left) and laboratory simulation (right)

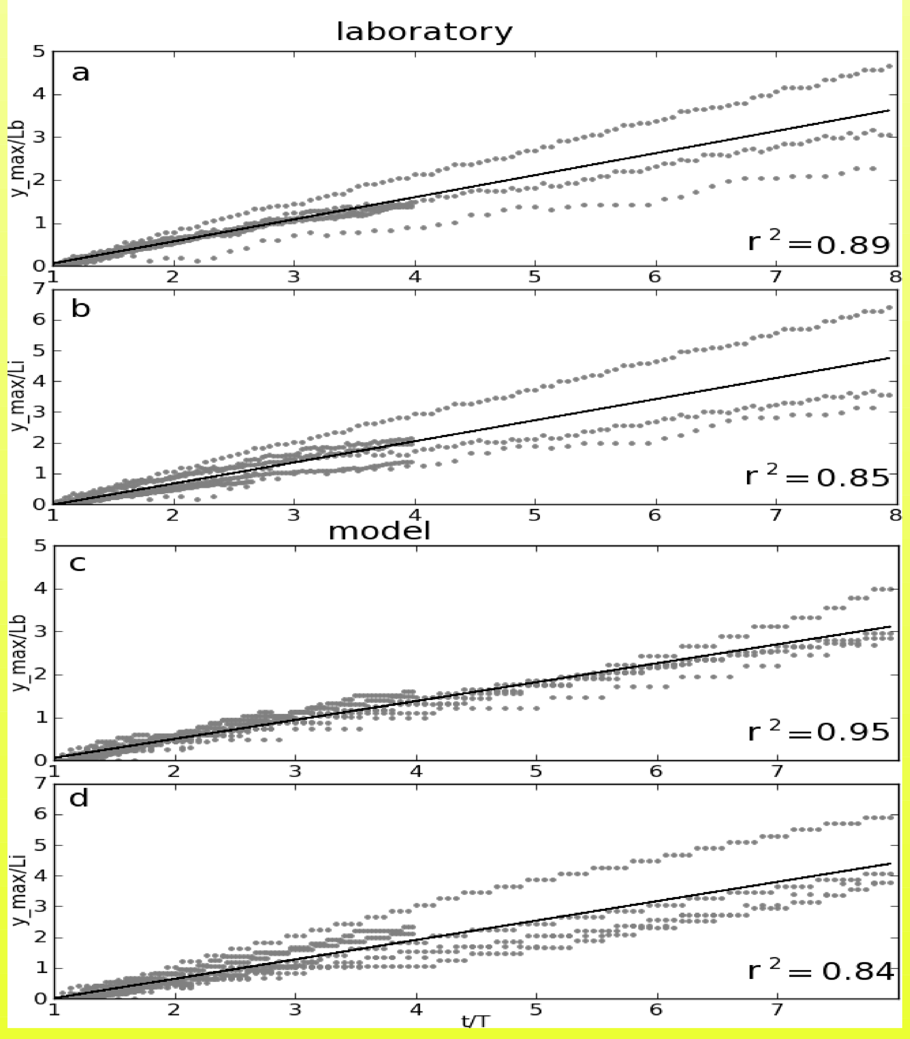
Table (->): Experimental parameters of the ROMS simulation and laboratory experiment pairs. The values listed are run number, rotation period, *T*[s], mean inflow rate *Q*[cm^3s^{-1}], inflow amplitude, *ΔQ*[cm^3s^{-1}], ambient salinity, S_0, Kelvin number, *K*.

Run nr	*T [s]*	*Q* [cm^3s^{-1}]	*ΔQ* [cm^3s^{-1}]	S_0	*K*
1	30	7,63	2,36	5	1,08
2	30	7,9	0	5	1,08
3	15	10,3	0	5	2,17
4	15	10	0	1	4,83
5	40	6	0	1	1,81
7	15	10,3	0	32	0,86
12	7,5	12,35	7,6	4,5	4,57
13	15	12,35	7,6	4,5	2,28
14	30	12,35	7,6	4,5	1,14
15	45	12,35	7,6	4,5	0,76
16	60	12,35	7,6	4,5	0,57
17	60	12,35	1,55	4,5	0,57
18	60	12,35	2,9	4,5	0,57
20	60	12,35	6,05	4,5	0,57

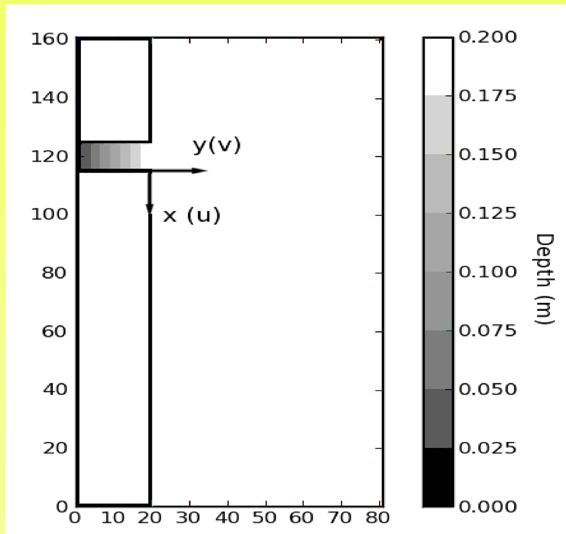
1. phase



2. phase



Bulge offshore spreading non-dimensionalized by bulge Rossby radius (a and c) and internal radius (b and d). All numerical and laboratory simulation runs are included. Figure illustrates scattering therefore distinguishing between runs are not important at that point. Solid line is linear regression and R^2 coefficient of determination.



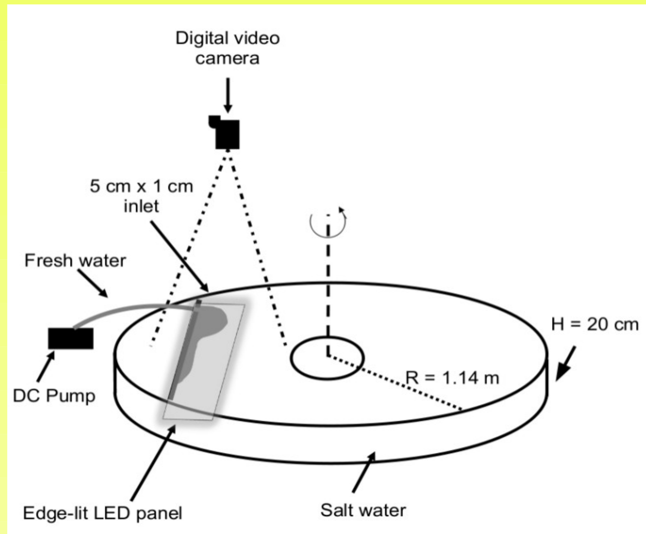


Figure: (left) Plan view of numerical model study domain. Study area size 30x80 cm with uniform 20 cm depth. (right) Sketch of the laboratory experimental setup. Monitored domain is marked with light gray rectangle. Colored fresh water is injected to the ambient salty water through 5x1 cm inlet trough gap in vertical Plexiglas wall imitating coastal wall in `western' direction.

Result

- Inflowing water forms a growing anti-cyclonic buoyant bulge and coastal current in all experiments.
- Two phases of bulge spreading:
  1) an initial fast spreading, 0.3-0.7 rotation periods (T)
  2) slow expansion until the end of the simulation (8T). The shift from first phase to second coincides with the formation of the coastal current.
- During second phase numerical bulge expands at a steady rate of 0.10cm s^{-1} and laboratory bulge at 0.11cm s^{-1}.

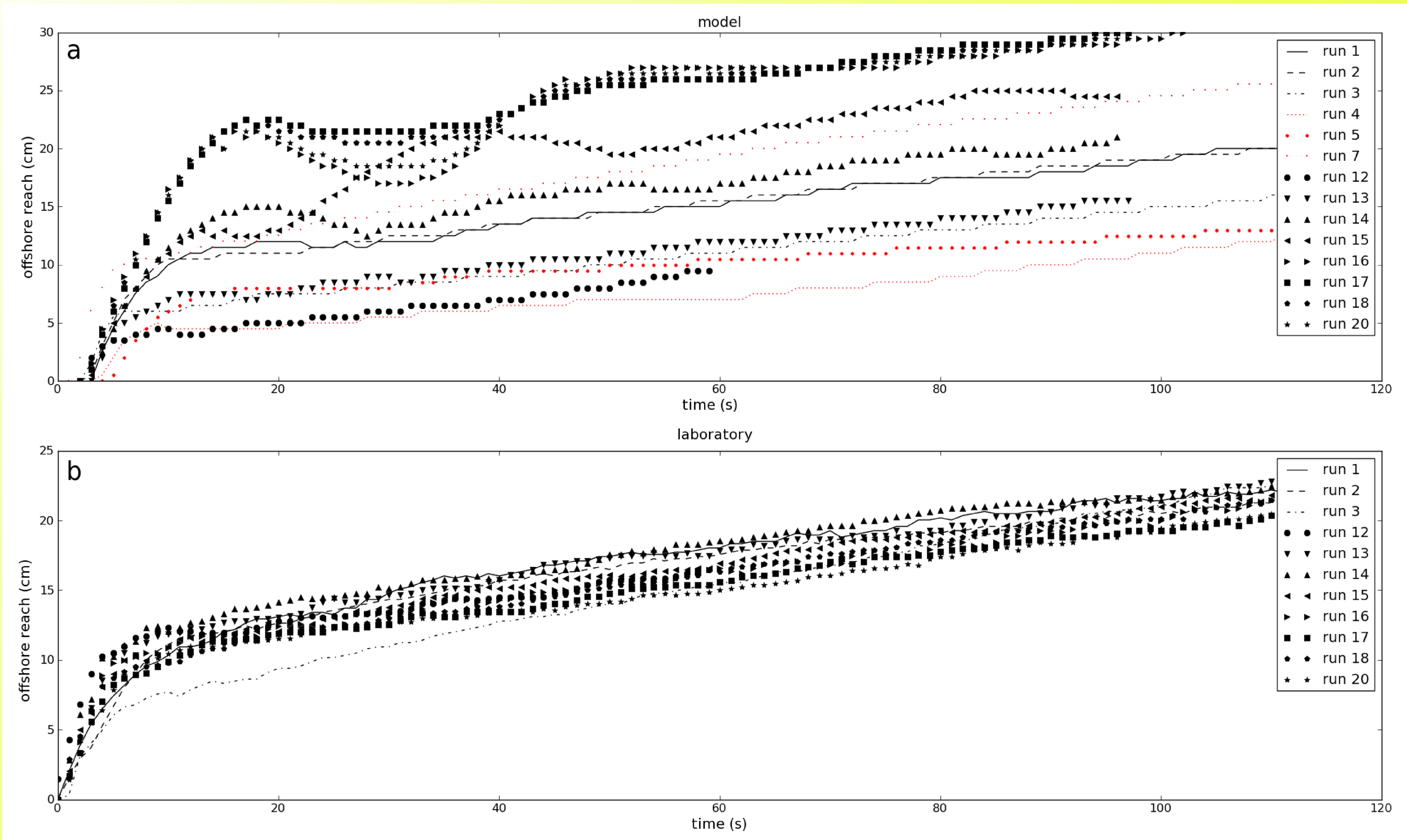


Figure: Bulge front maximum offshore reach over time for a) numerical model b) laboratory simulation. Runs 4, 5 and 7 (red) are numerical simulations without laboratory equivalents.

Summary

- Two spreading phases, for laboratory and numerical bulge.
- Laboratory and model bulge front spreading agree well when inflow Kelvin number K~1 .
- When *K*>1/*K*<1, the model underestimates/overestimates the bulge offshore reach.
- Flow is altered before entering main basin (estuary). Wide/narrow estuary (comparing to the deformation radius) result with non-uniform outflow profile. Differences in first phase do not notably alter the spreading during the second phase.
- First phase laboratory spreading scales with internal radius, model scales with inflow Rossby number.
- Second phase model and laboratory spreading scales with inflow Rossby number.

TALLINNA TEHNIKAÜLIKOOL
TALLINN UNIVERSITY OF TECHNOLOGY

TEXAS A&M UNIVERSITY