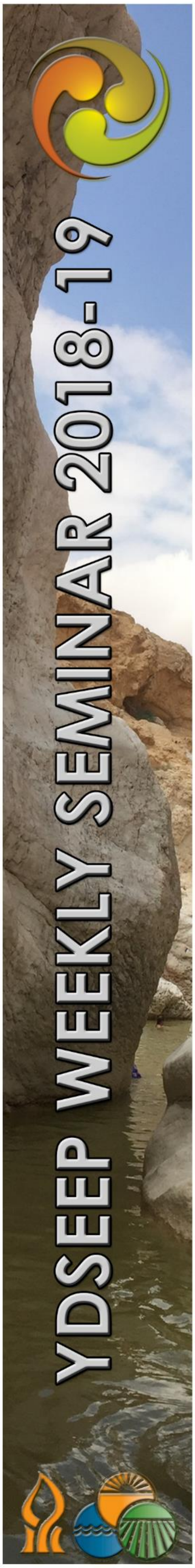

Ben-Gurion University of the Negev
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The flow of Gravity Currents and Intrusions: a test-case for the power and limitations of simple mathematical models in the prediction of complex phenomena

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Abstract

A gravity current appears when fluid of one density, ρ_c, propagates into another fluid of a different density, ρ_a, and the motion is mainly in the horizontal direction. A gravity current is formed when we open the door of a heated house and cold air from outside flows over the floor into the less dense warm air inside. A gravity current is formed when we pour honey on a pancake and we let it spread out on its own. A gravity current which propagates inside a stratified fluid (rather than along a boundary) is called "intrusion." Gravity currents (intrusions) originate in many natural and industrial circumstances and are present in the atmosphere, lakes and oceans as winds, cold or warm streams or currents, polluted discharges, volcanic ash clouds, etc. The efficient understanding and prediction of this phenomenon is important in numerous industrial, geophysical, and environmental circumstances.

Simple qualitative consideration and observations indicate that the gravity current is a very com- plex, multi-faced, and parameter-rich physical manifestation. Nevertheless, the gravity current also turns out to be a modeling-friendly phenomenon. Indeed, visualizations of the real flow field reveal an extremely complicated three-dimensional motion, with an irregular interface, billows, mixing, and instabilities. The accurate numerical simulation of this flow by the full set of governing equations (the Navier-Stokes system) requires weeks of number-crunching on powerful computer arrays; then, the huge amount of numerical data must be processed and averaged for a comprehensive interpretation and analysis by engineers and technicians. On the other hand, there are "mathematical models" for the gravity current, whose derivation is based on a long line of assumptions such as hydrostatic pressure, sharp interface, Boussinesq system, thin layer, idealized release conditions.

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Date & Location:

Tuesday, March. 12, 2019, 11:00
Lecture room, Physics Building (ground floor)

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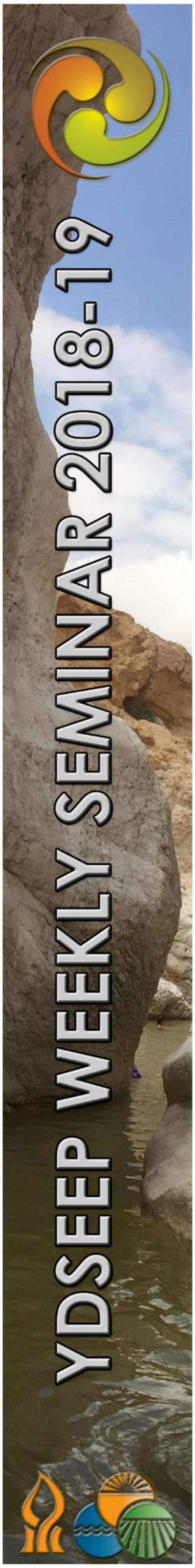

Abstract - Continue

This simplified set of equations enables us to determine the behavior of the major averaged variables entirely from analytical considerations and/or numerical solutions that require insignificant CPU time. Recent studies demonstrate that this approximate formulation can be extended successfully to complicate circumstances: non-Boussinesq systems, flows in channels of general cross-section, and more.

The lecture gives a brief presentation of some typical models and solutions. We show that: (a) Qualitatively, the simplified theory is able to provide the governing dimensionless parameters and the salient features of the various flow regimes; and (b) Quantitatively, the simple models predict velocities of propagation which agree with experiments and full Navier-Stokes simulations within a few percent, typically within the range of the experimental errors. We argue that the gravity-current analysis can be considered a test-case for the methodology of flow-field modelling: the fact that simple models give useful predictions is a result of well-selected physical components. The implementation of this conclusion in the selection of reliable tools for practical applications is discussed.

References

[1] M. Ungarish. An Introduction to Gravity Currents and Intrusions. Chapman & Hall/CRC press, Boca Raton London New York, 2009.

[2] M. Ungarish. Thin-layer models for gravity currents in channels of general cross-section area, a review. Environmental Fluid Mech., 18:283–333, 2018.

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