The University Of Sheffield.

Department Of Mechanical Engineering.

Giulio Dolcetti[a], Anton Krynkin

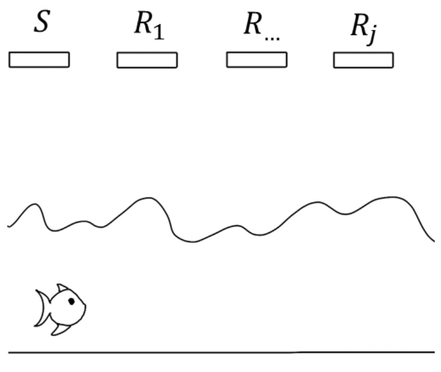
[a]: g.dolcetti@sheffield.ac.uk

RECONSTRUCTION of the rough water SURFACE profile with an acoustic imaging technique

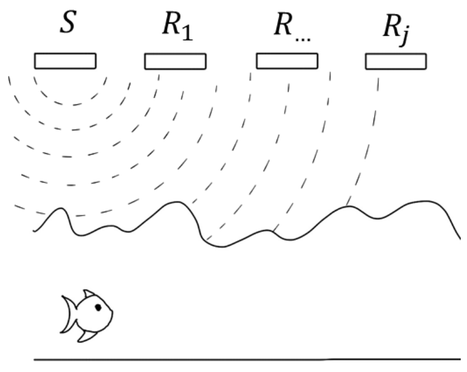
- Floods damages cause £1.1b annual cost in England.[1]
- Existing technologies to monitor free surface flows - invasive and expensive.
- **To overcome the limitations of traditional methods and enhance them, we propose acoustic remote monitoring techniques.**

- Fluid dynamic results[2]: **spatial and temporal scales** of the free surface relate directly to the **main hydraulic quantities of shallow flows**.
- Acoustic results:[3] **Reconstruction of the free surface** shape and dynamics based on holographic principles.

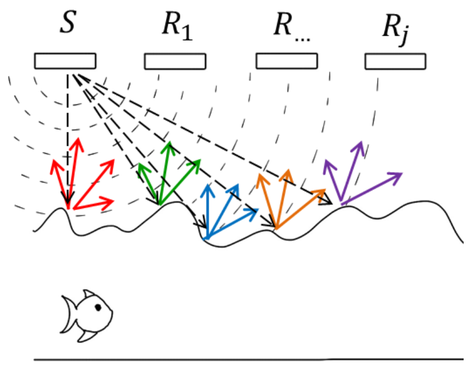
- **Principle of operation of the acoustic imaging technique applied to a rough surface profile:**



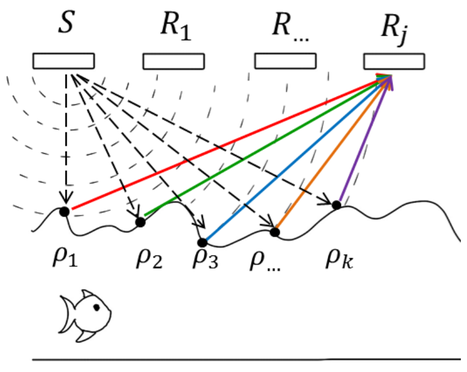
1. Ultrasonic source S and array of acoustic receivers R_j above the water surface.



2. The source emits a continuous harmonic signal (wave).

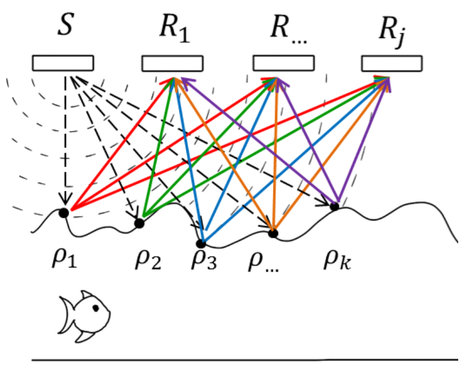


3. The acoustic wave is scattered in all directions by the rough surface.



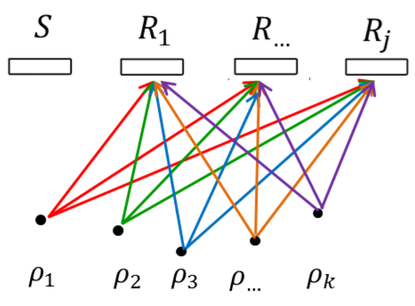
4. The acoustic pressure P at a single receiver R_j is the sum of the reflections from all points ρ_k on the surface,

$P(R_j) = \sum_k h(\rho_k, M_j) e(\rho_k, \eta_k).$



5. Same for each receiver. The problem has a matrix form:

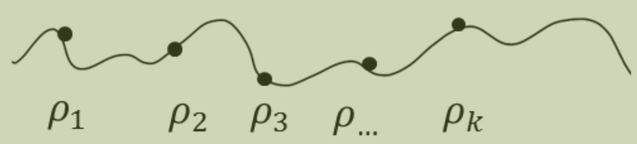
$P_{N_R \times 1} = H_{N_R \times N_k} E_{N_k \times 1}.$



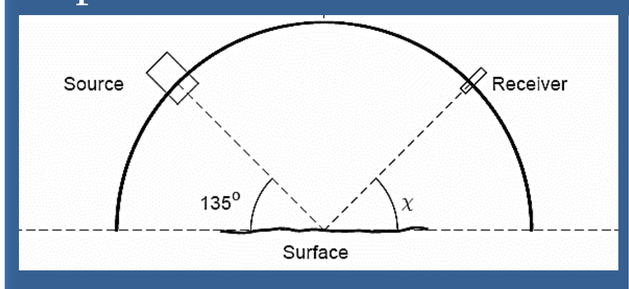
6. Inversion of the linear problem with holographic techniques to recover E.

7. Reconstructed surface elevation $\eta(\rho_k)$ from the elements of E:

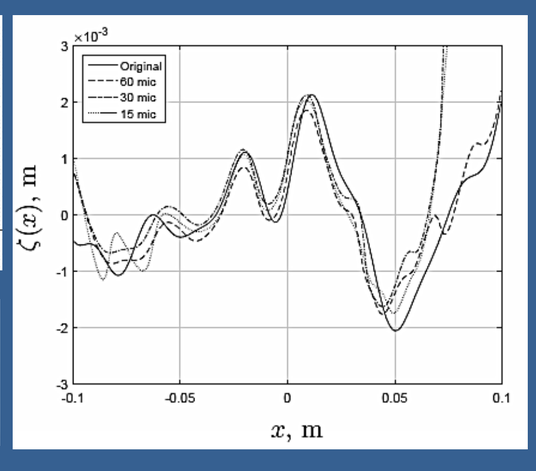
$$\boldsymbol{\eta(\rho_k) = -\frac{\Im[\ln e_k]}{q_z}}$$



Experimental validation. Two-dimensional surface[3]:

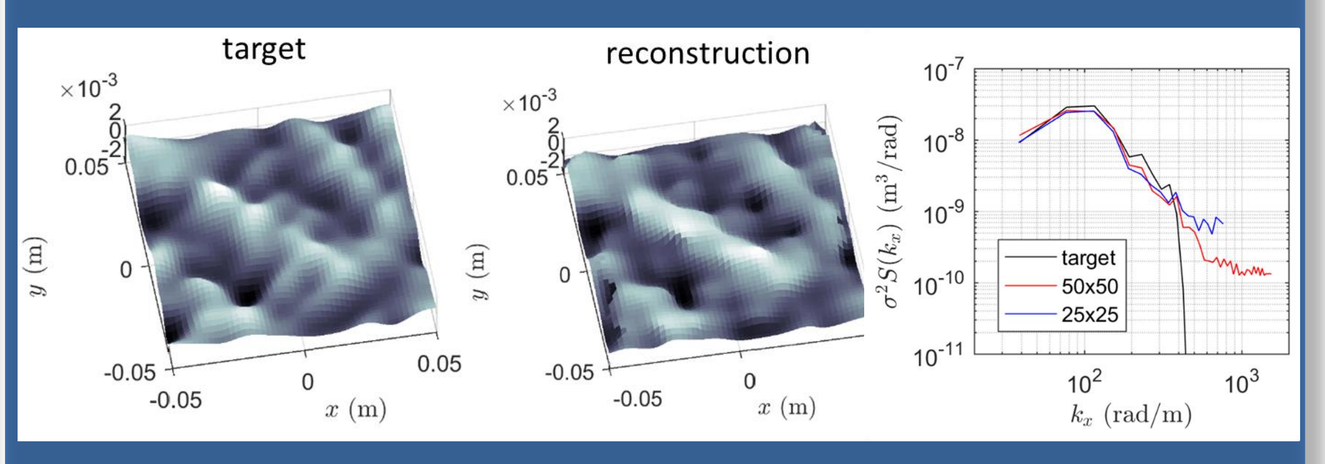


3D printed composite rough surface.
20, 30, 60 receivers.
150 reconstruction points.



(solid) Target surface.
Reconstruction with 60 (dashed-dotted), 30 (dashed) and 15 (dotted) receivers.

Three-dimensional surface:



Numerical simulation.
7x7 (49) sources and receivers. 50x50 (2500) reconstruction points.

Surface spatial spectrum.

[1]: Bennett, O. (2014), House of Commons Library Standard Note SN/SC/5755. London: UK Parliament
[2]: Dolcetti G., et al., Physics of Fluids 28, 105105 (2016).
[3]: Krynkin A., et al., Review of Scientific Instruments, *in press* (2017).