

Modulating Incipient Entrainment of Coarse Particles: The Impact of Flow Turbulence

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INTRODUCTION & AIM

- **Core Issue:** Turbulent flows entrain coarse particles, driving morphodynamics & scour hazards.
- **Gap:** Shields criteria miss turbulence effects; indirect tools (ADV) can be costly.
- **Aim:** Link flow dynamics to entrainment thresholds using IMUs embedded in sediment particles.
- **Hypothesis:** Turbulent scales that are important for sediment particle entrainment should be linked to the probability of particle motion [1].

METHOD

- **Particle:** 3 cm shell w/ IMU (accel $\pm 16g$, gyro $\pm 2000^\circ/s$, mag.; 1000 Hz, >1 hr) [2,3].
- **Calibration:** Rolls/pendulums/inclines; fusion error <1.1% [2,3].
- **Setup:** Flume (10 m, gravel bed); ramped flows (0.2–0.5 m/s); ADV sync [1,3].
- **Metrics:** f_e , P_E , RR from fused data [1].



Figure 1. A side-view the instrumented particle resting on the 3D-printed local bed-topography in the test section before starting the experiment [1].



Figure 2. Demonstration of the instrumented particle showing the MEMS sensor encapsulated with the 3D printed waterproofed casing (with external diameter of 3cm). [2]

RESULTS & DISCUSSION

- ✓ **Key Findings:** Bursts: $500^\circ/s$ angular spikes, lift $\uparrow 30\text{--}50\%$; thresholds $\downarrow 15\text{--}25\%$ [1,3].
- ✓ **Trends:** $f_e \uparrow 0.4\text{--}6.5$ entr/min w/ Re_p (1800–2000); TKE explains 80% variance; sweeps = 70% impulse [1].
- ✓ **Limits:** Lab-scale; flood validation needed.

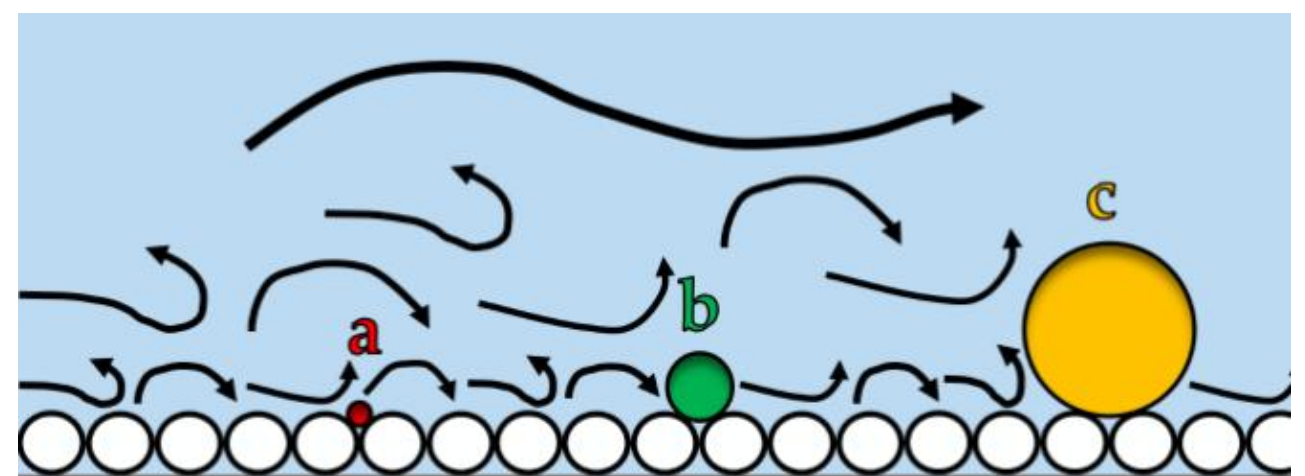


Figure 3. Demonstration of flow structures of different length scales impinging on exposed particles resting on the bed surface [1]

CONCLUSIONS

- ❑ IMUs reveal turbulence-driven entrainment; metrics (f_e/PE) enable real-time risks.
- ❑ Impact: Low-cost monitoring for resilient infrastructure/rivers.

FUTURE WORK

- Field IoT trials; AI predictions;
- Goal: Step towards Civil Infrastructure 4.0 and Digital Twins.

REFERENCES

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