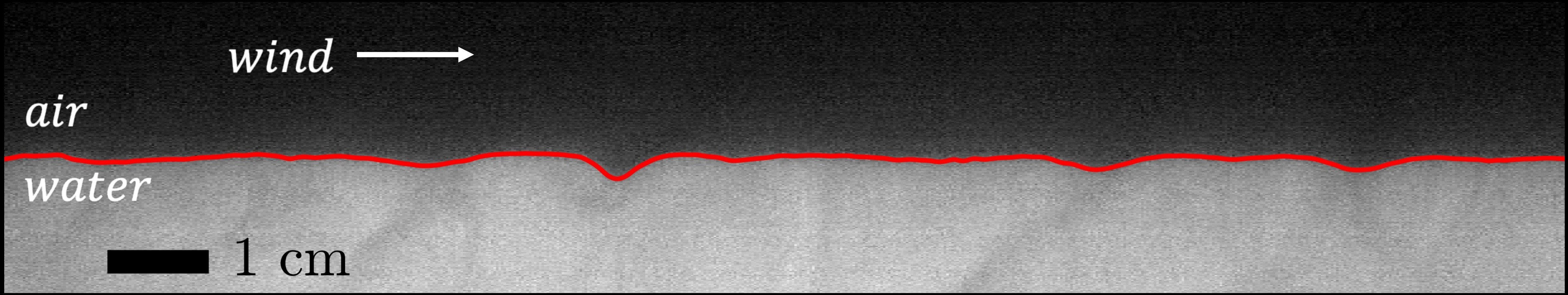
Wind generated wrinkles on the ocean surface



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Fabio Addona[2], Fabrice Veron[2]

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2. University of Delaware

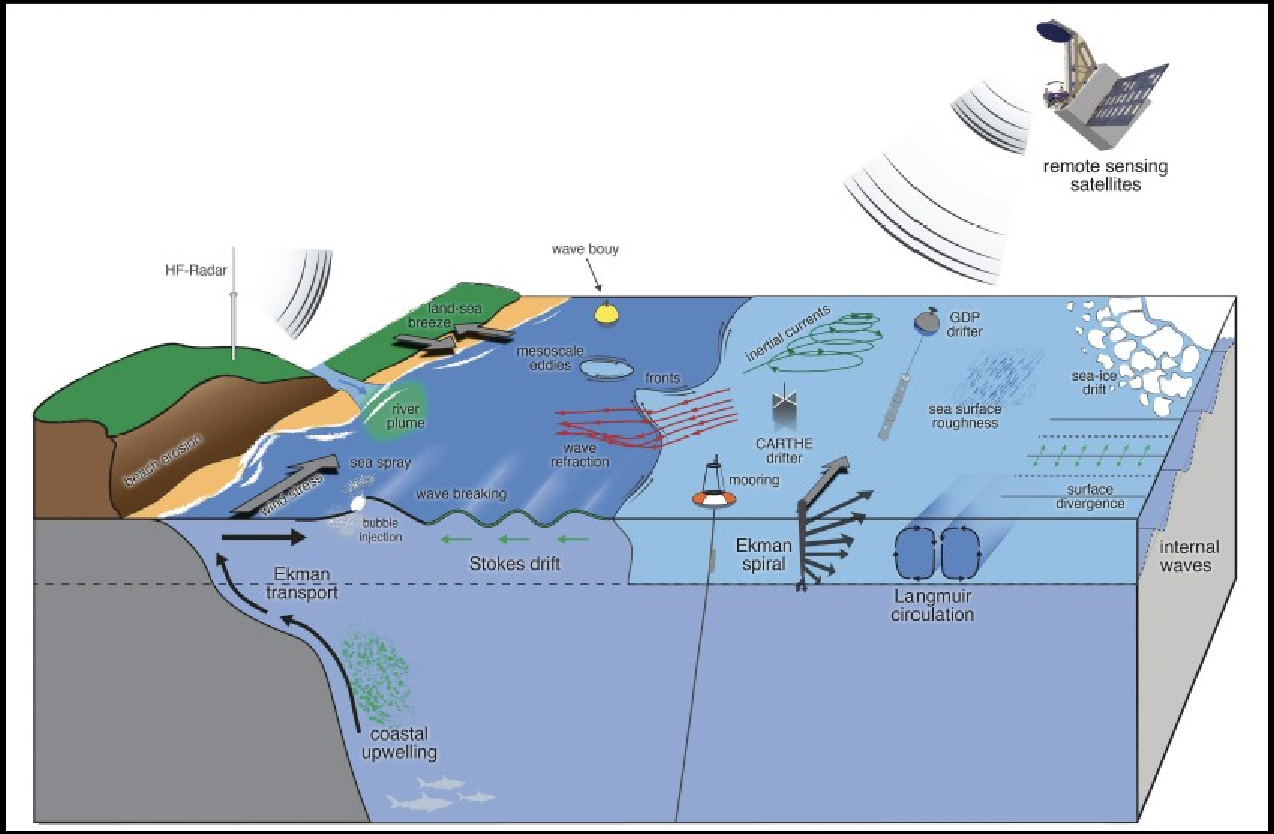
Heterogeneous and unsteady ocean surface*

*See also Luc and Mara's talk, and Kayli's poster

Measuring winds and currents: knowledge of short waves

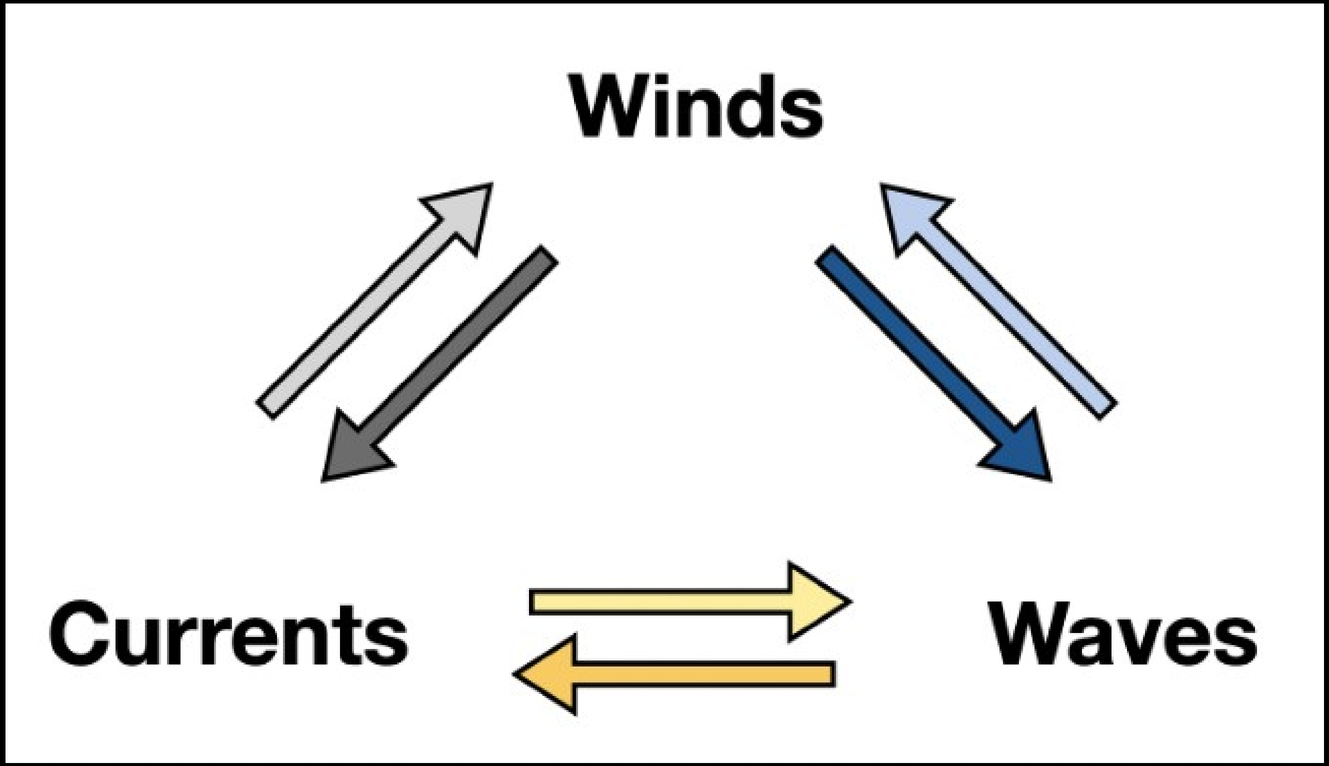
Bragg scattering predominantly supported by gravity-capillary waves

L, X, K bands of radar scatter off waves of length tens of cm, cm, mm



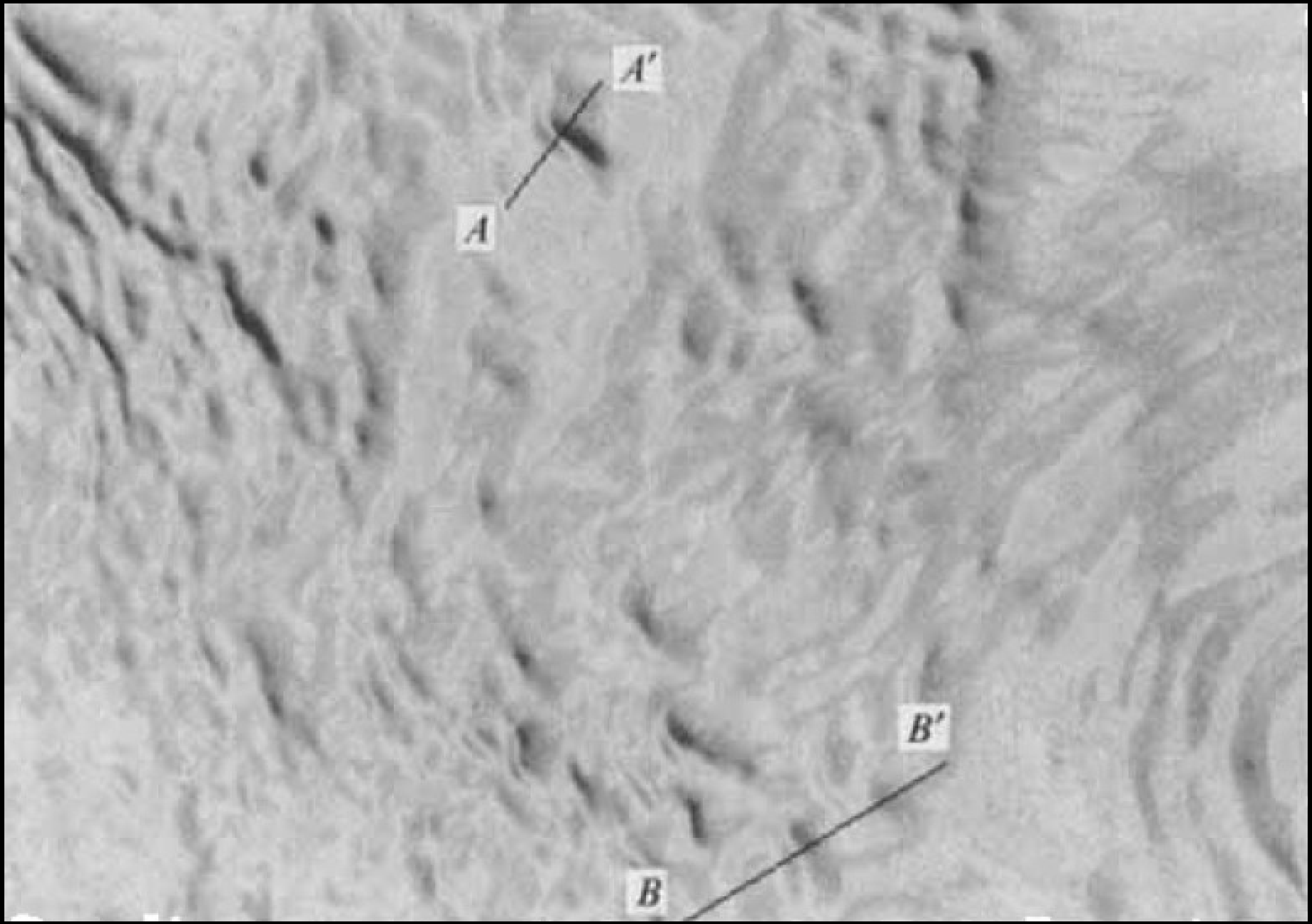
Villas Boas et al. (2019), see also Bourassa et al. (2019)

How does free surface geometry (roughness) depend on the coupling between winds, waves and currents?



Villas Boas and Pizzo (2021)

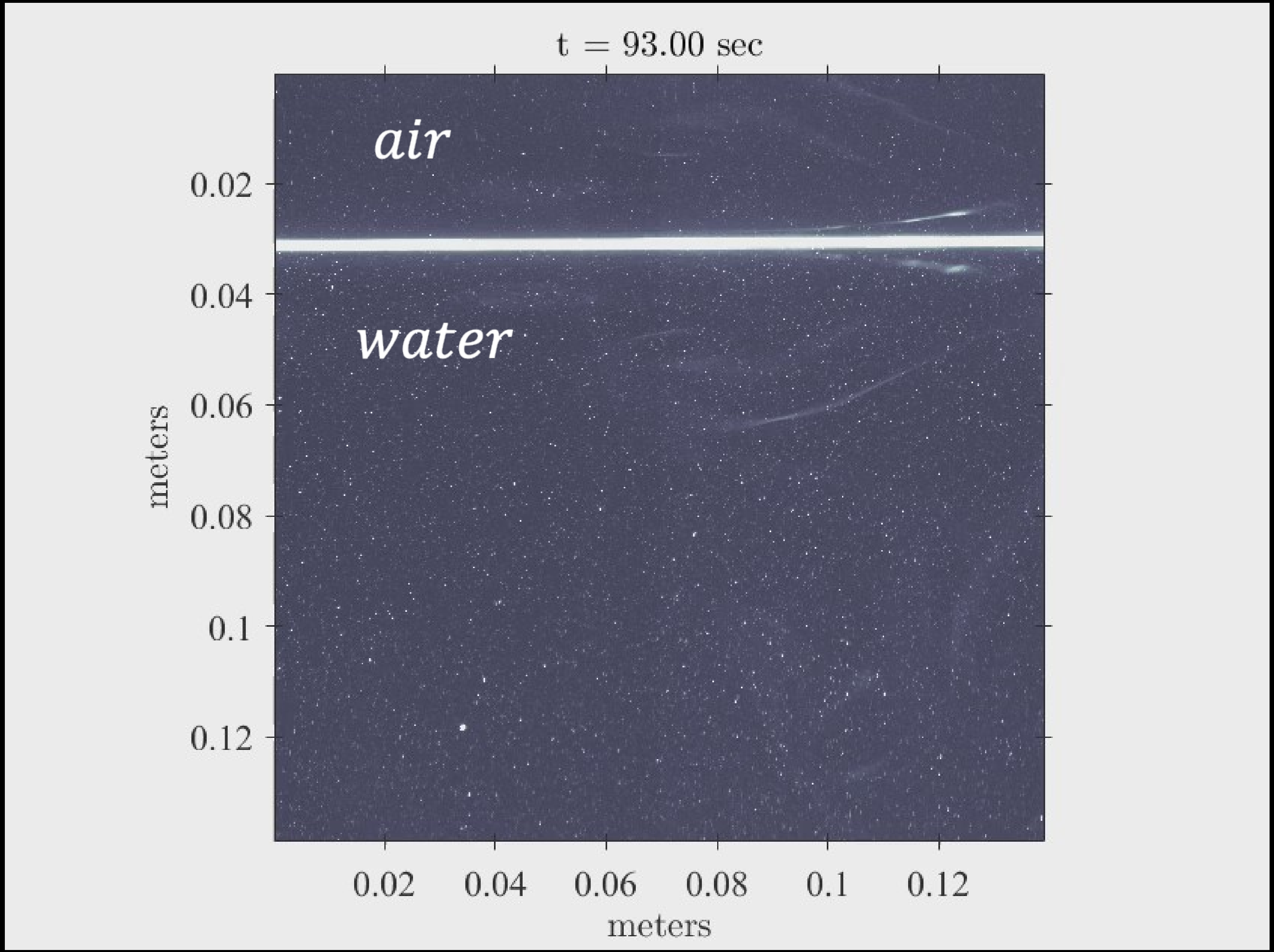
Simpler question: how are the initial wrinkles on the ocean surface formed?



Zhang (1995)

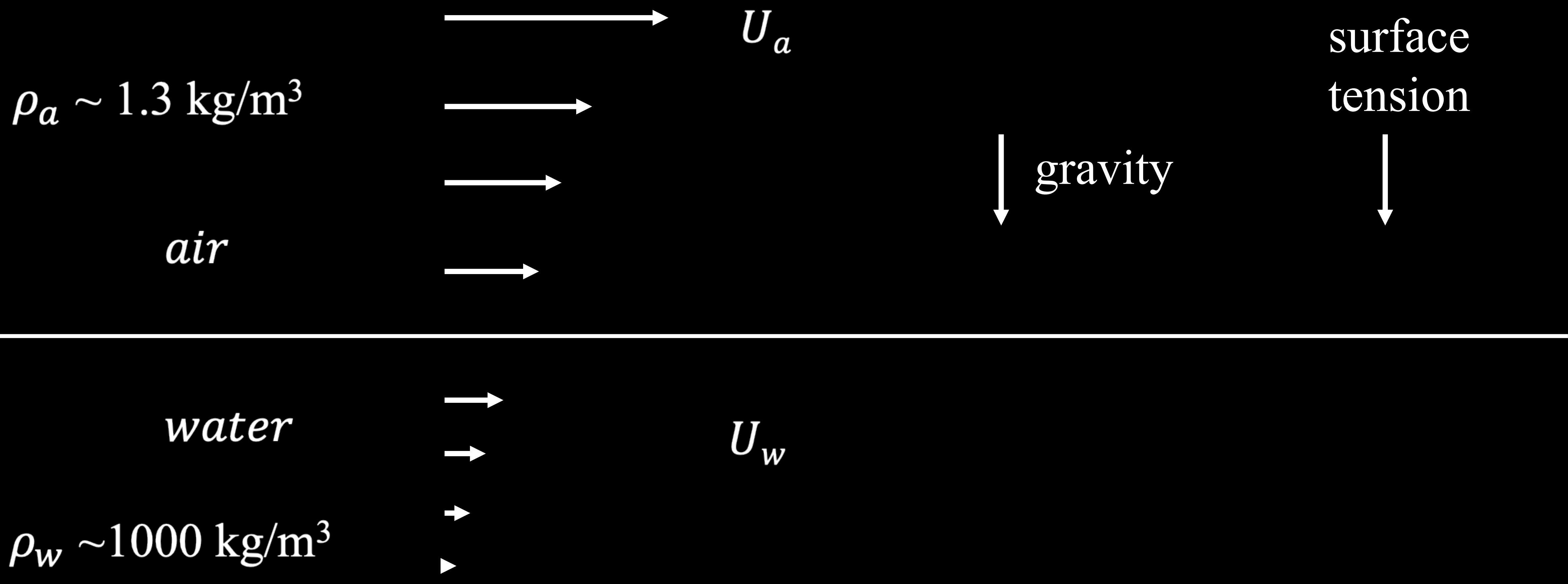
When wind blows, waves can be created which catalyze vertical (turbulent) fluxes of heat and momentum

$\otimes$
wind



Wagner, Pizzo, Lenain and Veron (2023)

Problem set up



A bit of history: wave generation by wind

Pizzo, Deike & Ayet (2021)

Miles (1957): wind induced instability excites gravity waves of wavelengths greater than 1 meter

Instability growth rates from wind scale like $\frac{\rho_a}{\rho_w} \sim 10^{-3}$

Wave generation by currents (generated by wind)

Young and Wolfe (2014): current induced “rippling” instability, requires surface speeds exceeding 23 cm/s (minimum gravity-capillary wave speed)

Instability growth rates from currents scale like $\frac{\rho_w}{\rho_w} = 1$

exponential profile used here. However, in the laboratory, ripples first appear at surface speeds significantly less than 23 cm s^{-1}, e.g. in Veron & Melville (2001) ripples appear at a surface speed of $\sim$16 cm s^{-1}. We have no explanation for this significant difference between the laboratory and linear stability theory. This is, of course, not the

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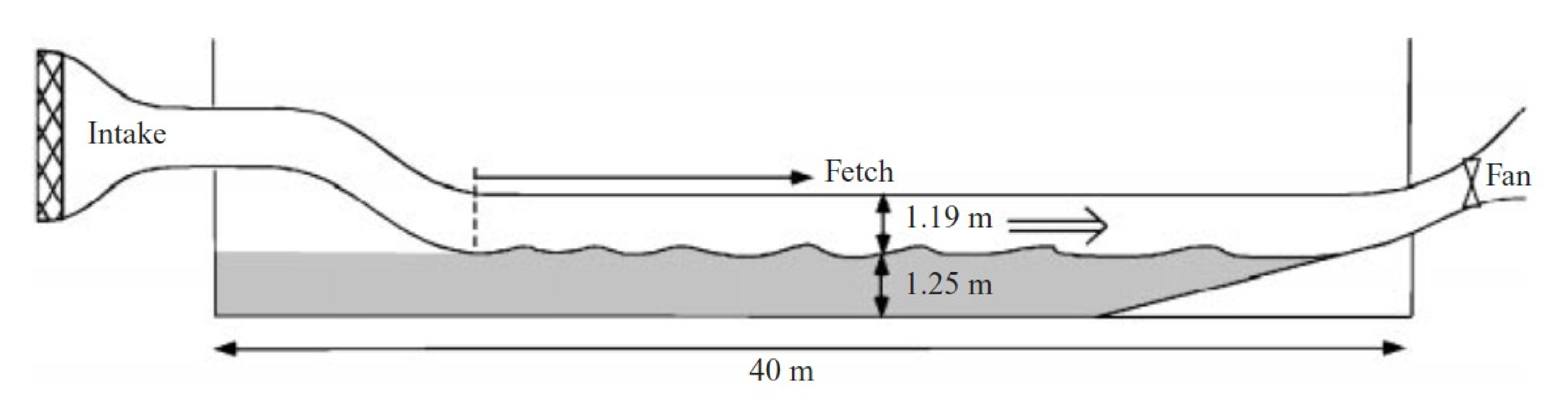
Theories are limited (e.g. steady uniform currents, periodic waves).

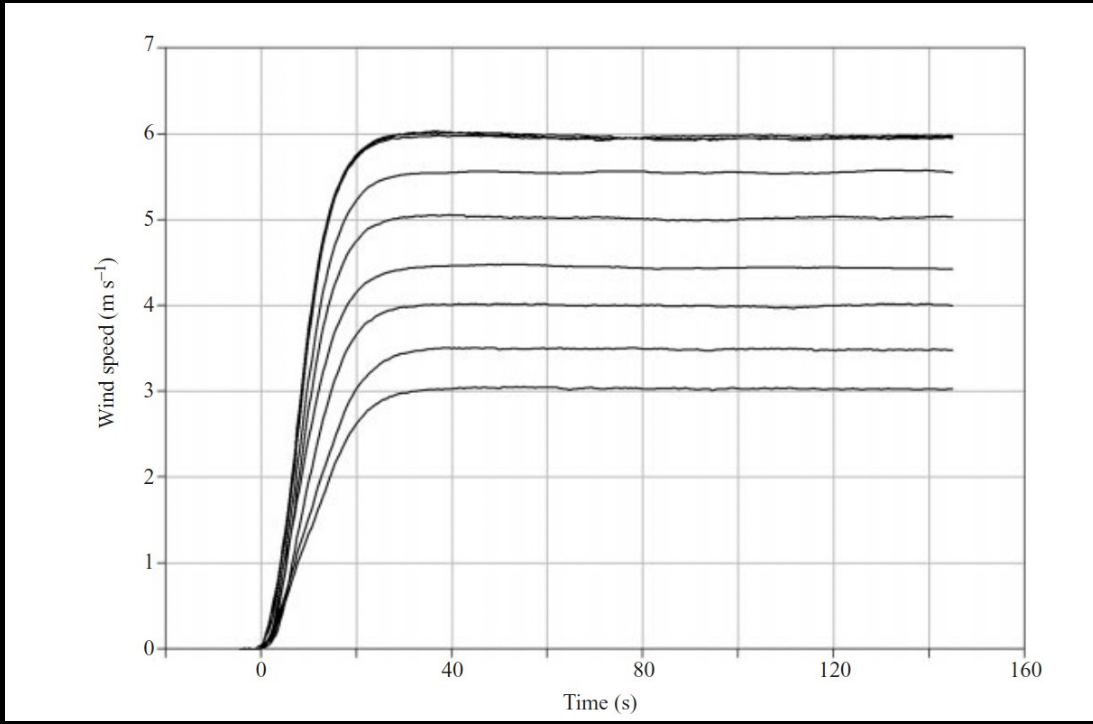
How are these initial wrinkles generated?

Laboratory approach to studying ripples



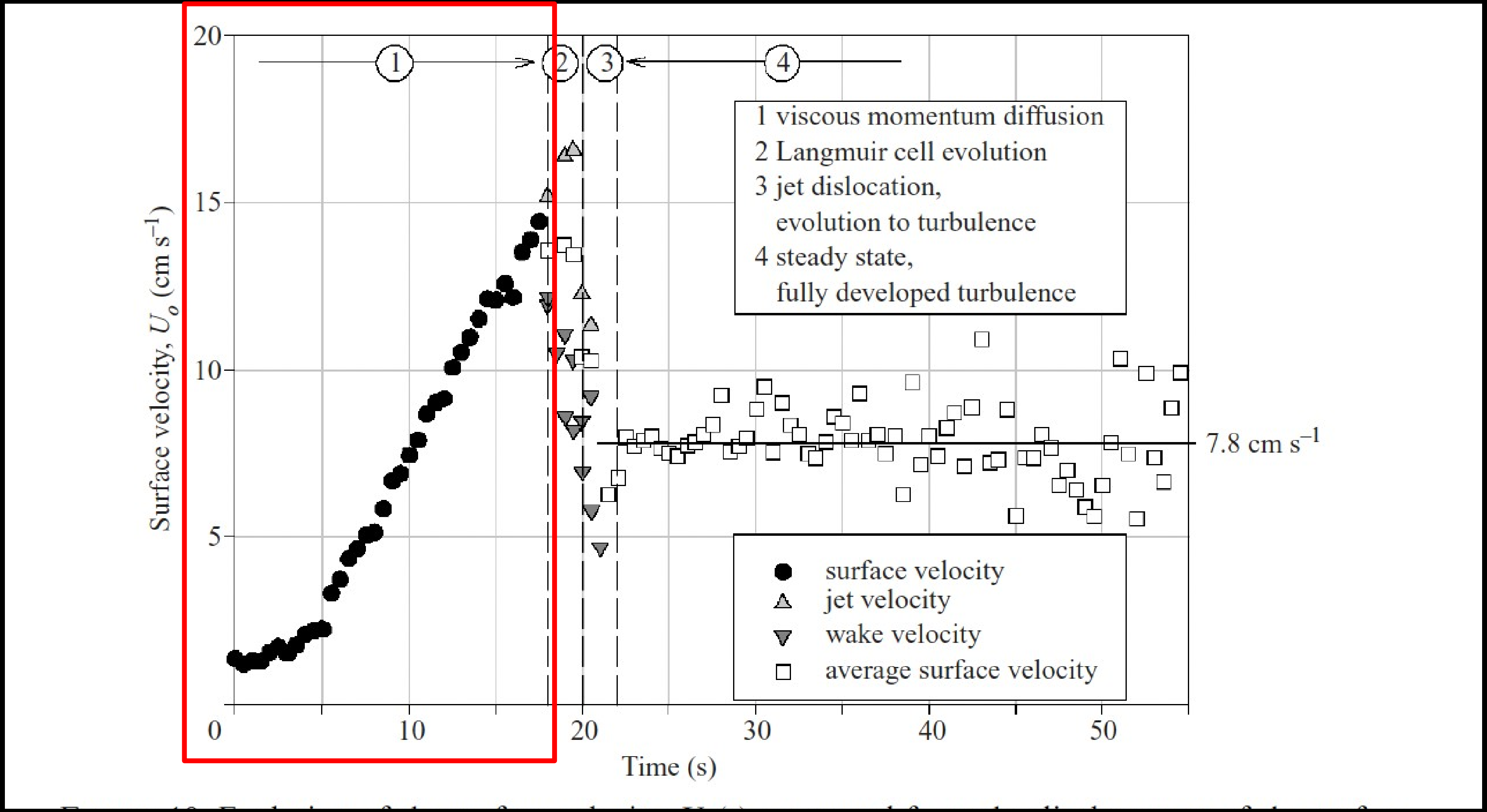
Veron and Melville (2001), Wagner, Pizzo, Lenain, Veron (2023)

Wind evolution: time dependent problem



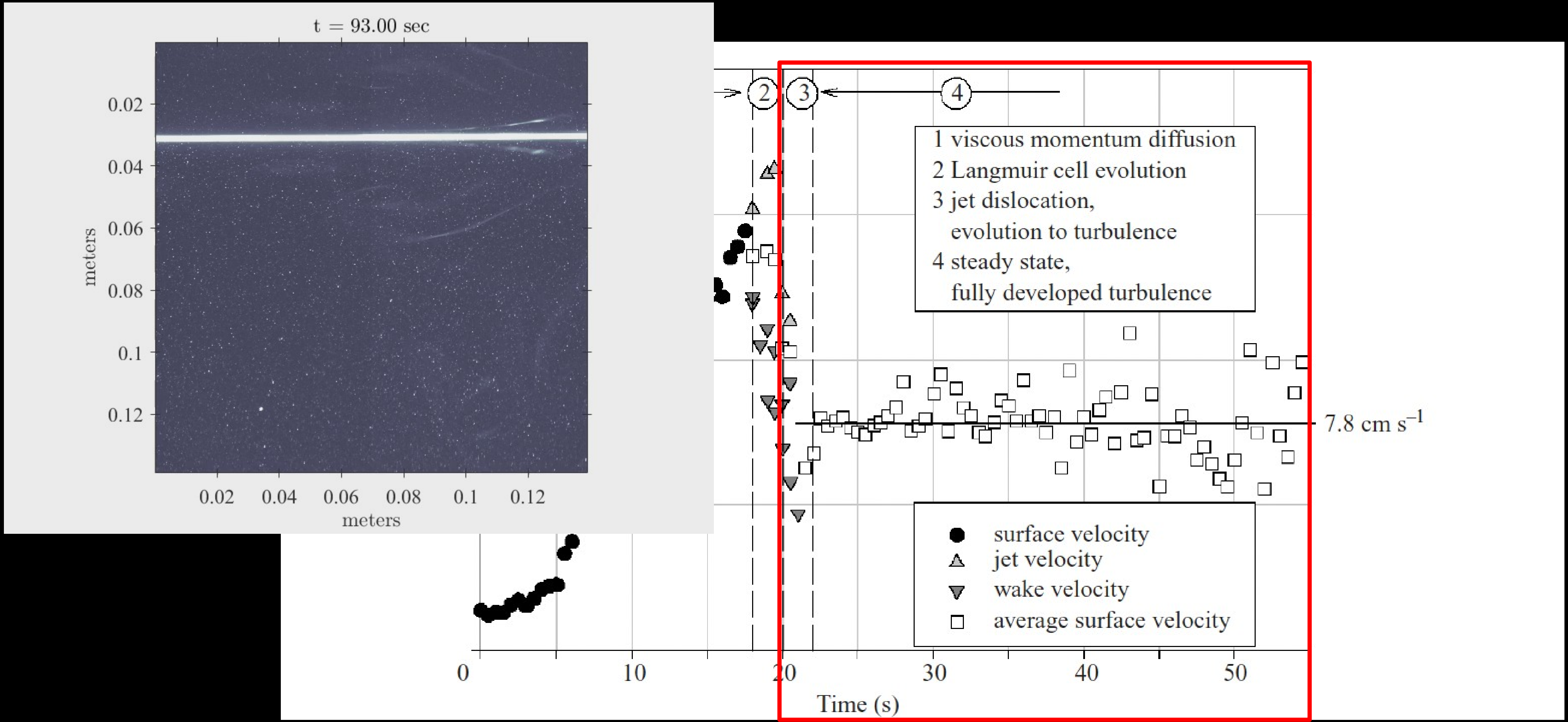
Veron and Melville (2001)

I. Initially flow is laminar, free surface is flat and linear theory applies



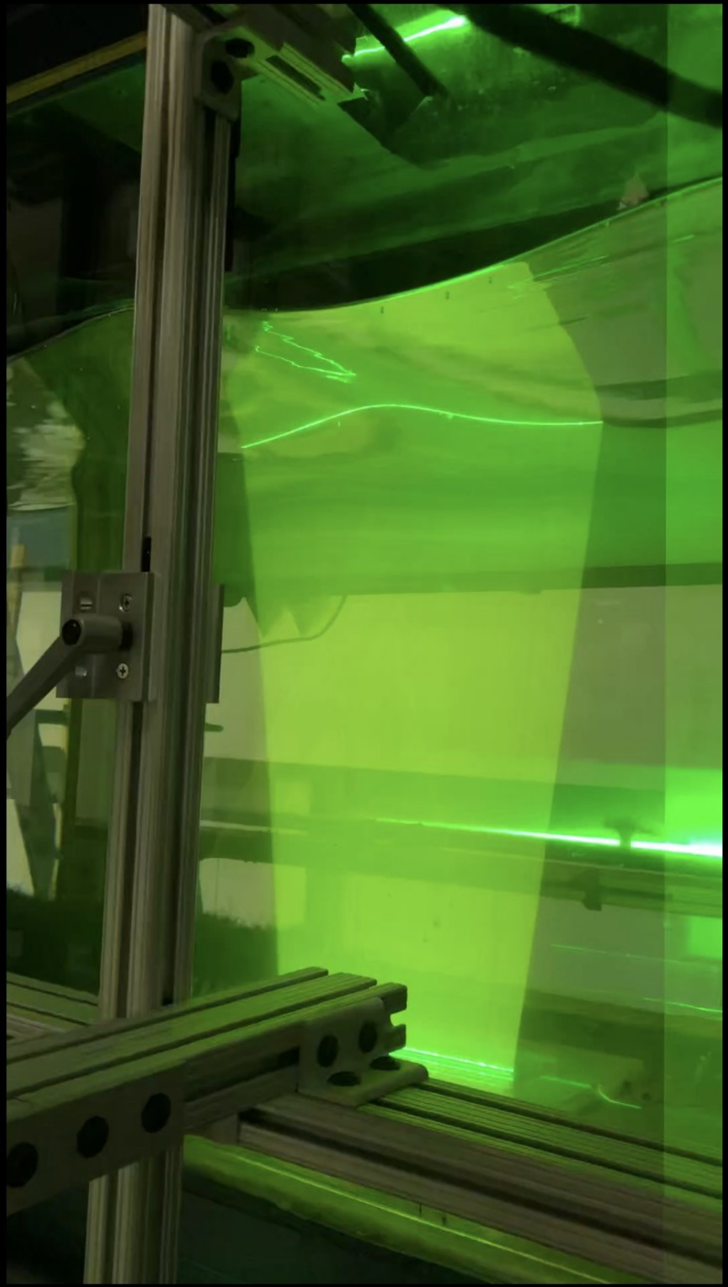
Veron and Melville (2001)

II. Wave creation and Langmuir turbulence



Veron and Melville (2001)

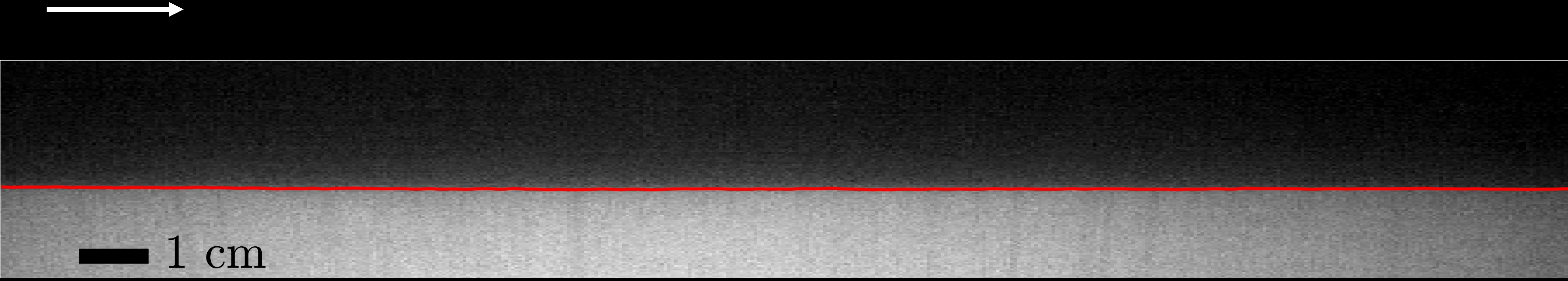
Surface detection along 2-dimensional slice



*We have air and water side PIV (velocities) and surface currents

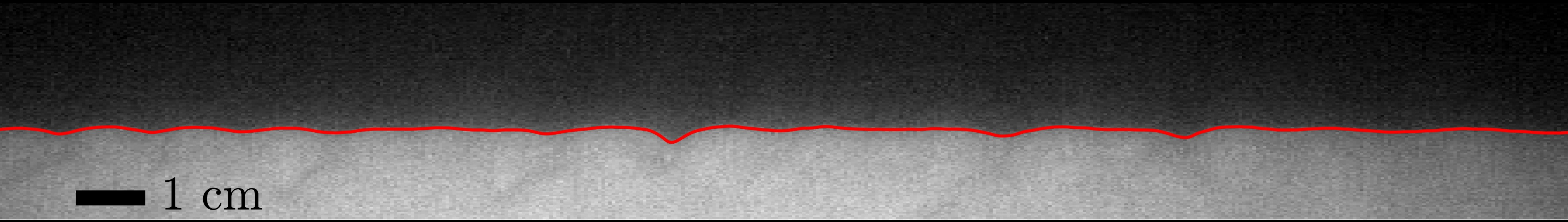
Initial free surface (in red) behavior: wind is blowing, no waves

$wind$



Wave onset characterized by lumps

wind



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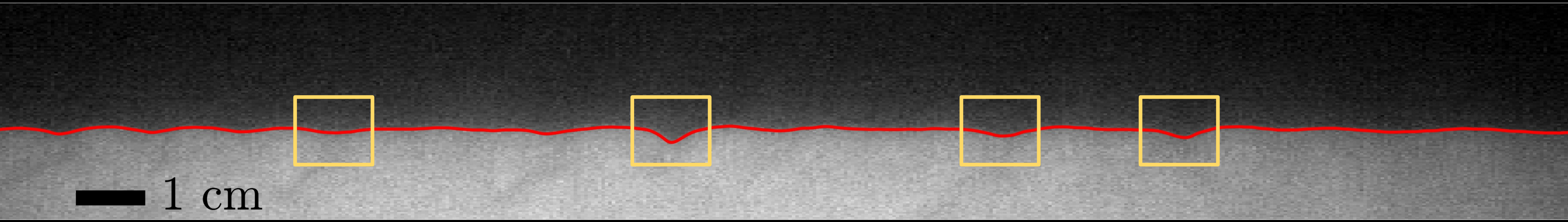
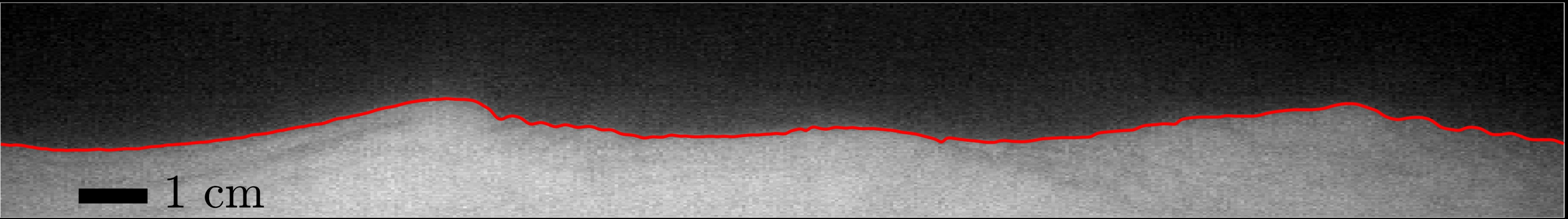


Long time evolution: gravity-capillary waves, parasitic capillaries

wind



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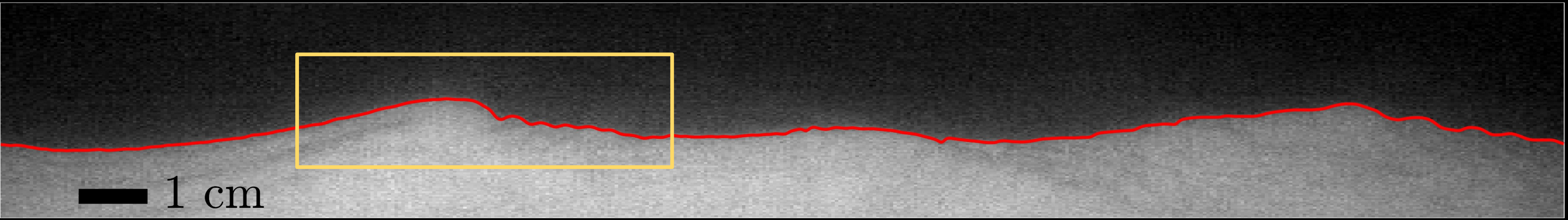
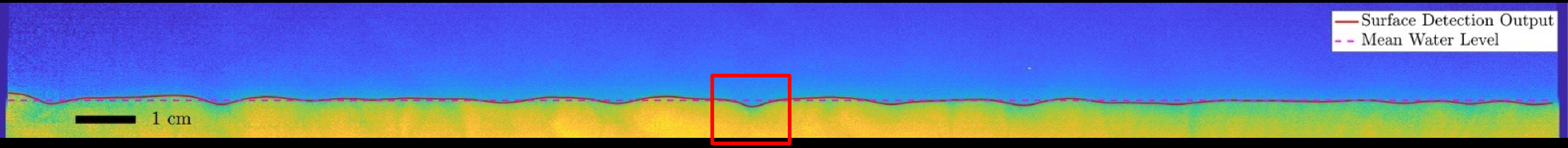
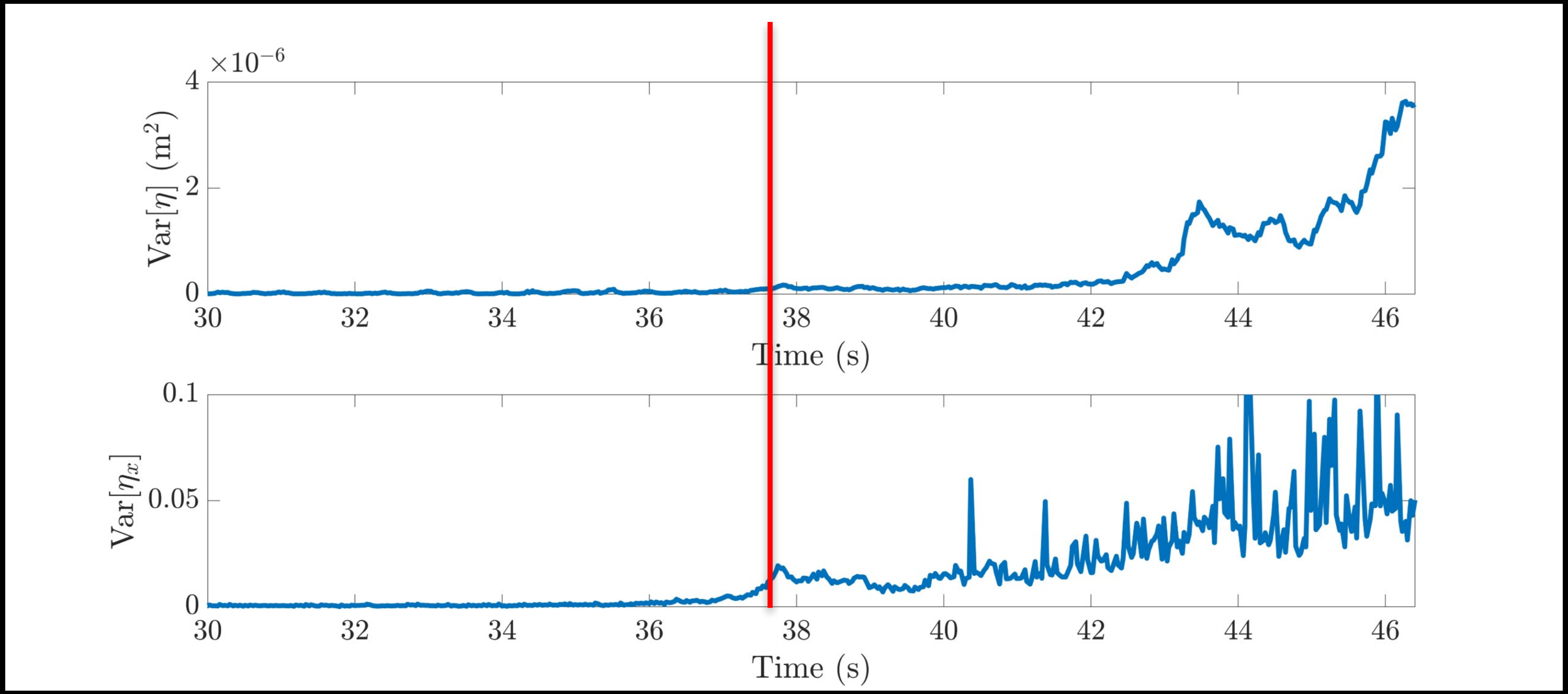


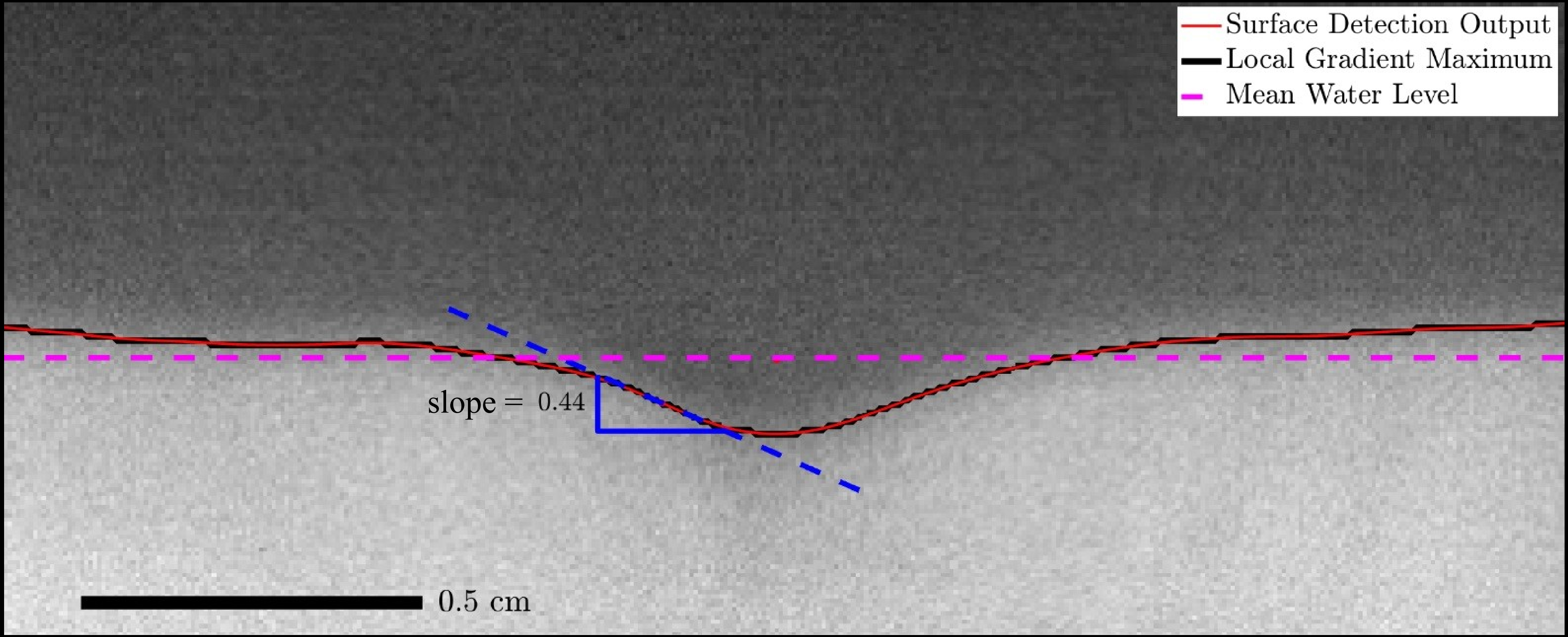
See also Deike et al. (2015)

Wrinkles appear once free surface slope becomes non-zero

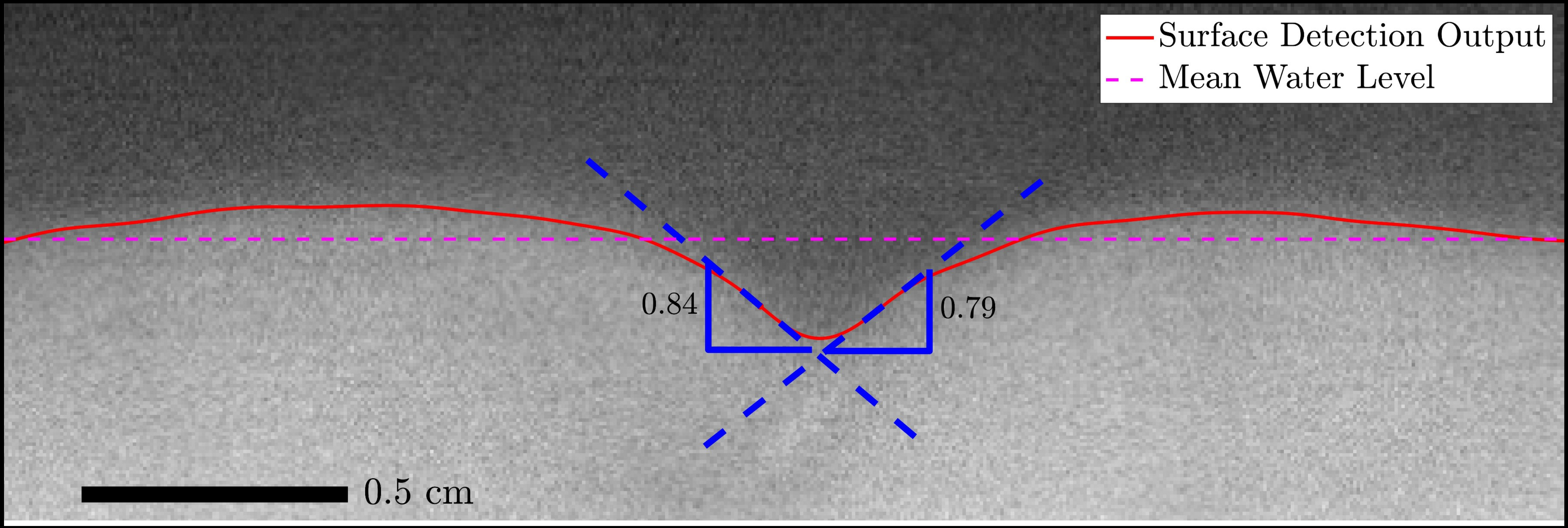




Flatter crests, steeper troughs (c.f. gravity waves)

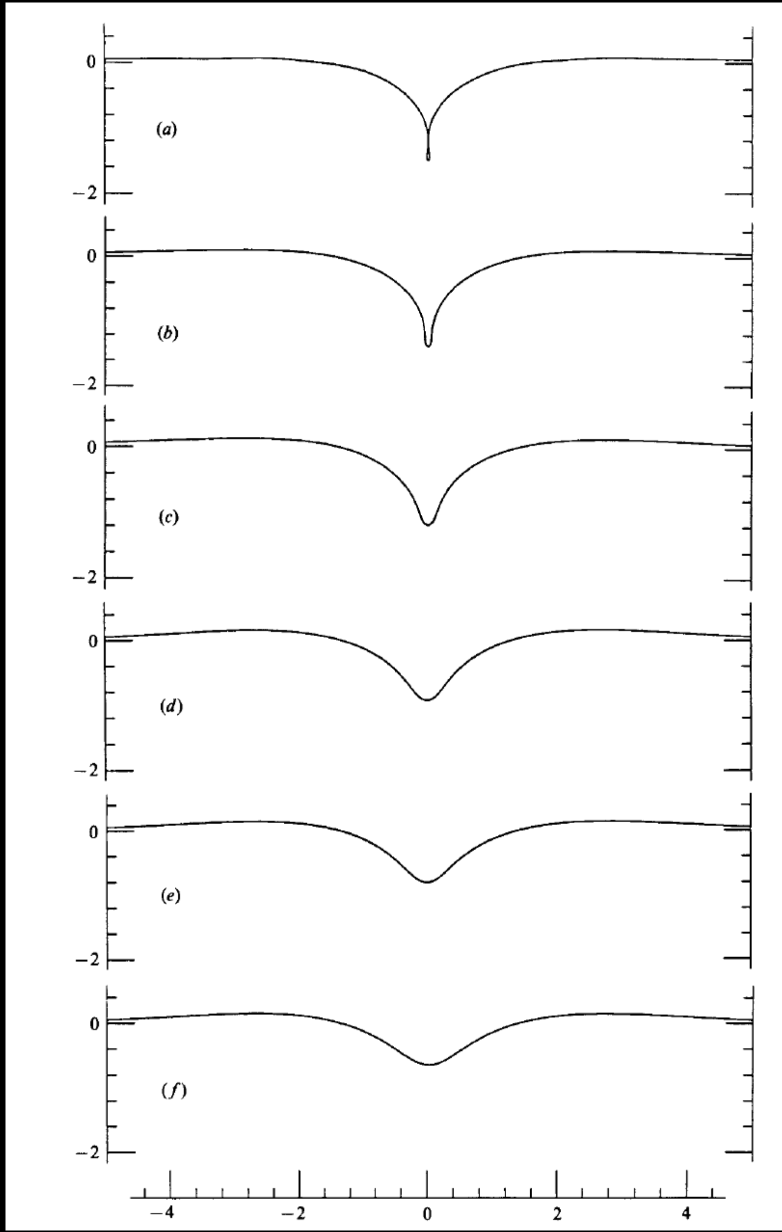


Compact, relatively steep (nonlinear)



Geometry differs strongly from linear periodic predictions

Gravity-capillary solitons: geometry

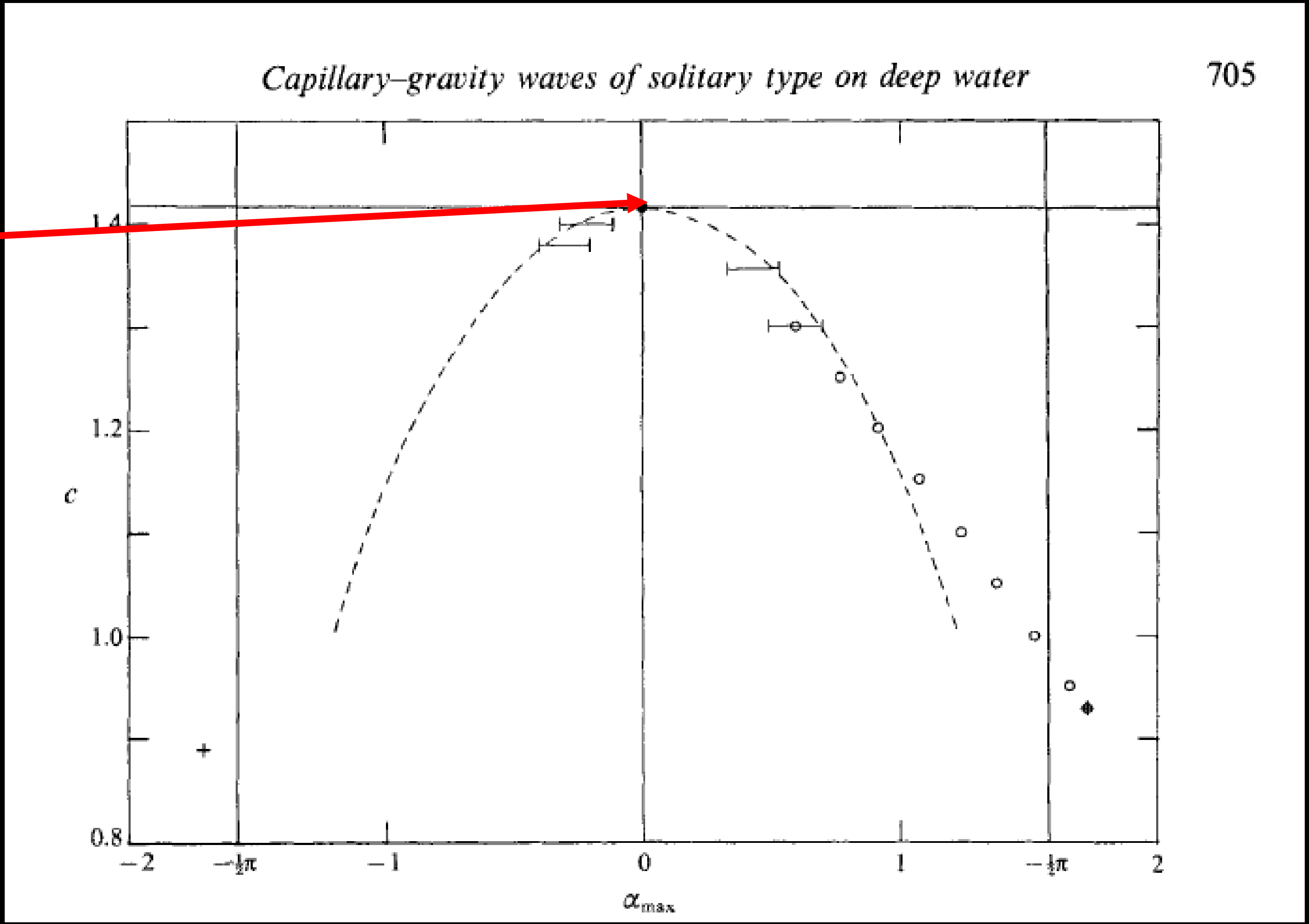


Solitary waves: dispersion and nonlinearity balance

Longuet-Higgins (1989, 1993)

Kinematics: steeper waves travel slower

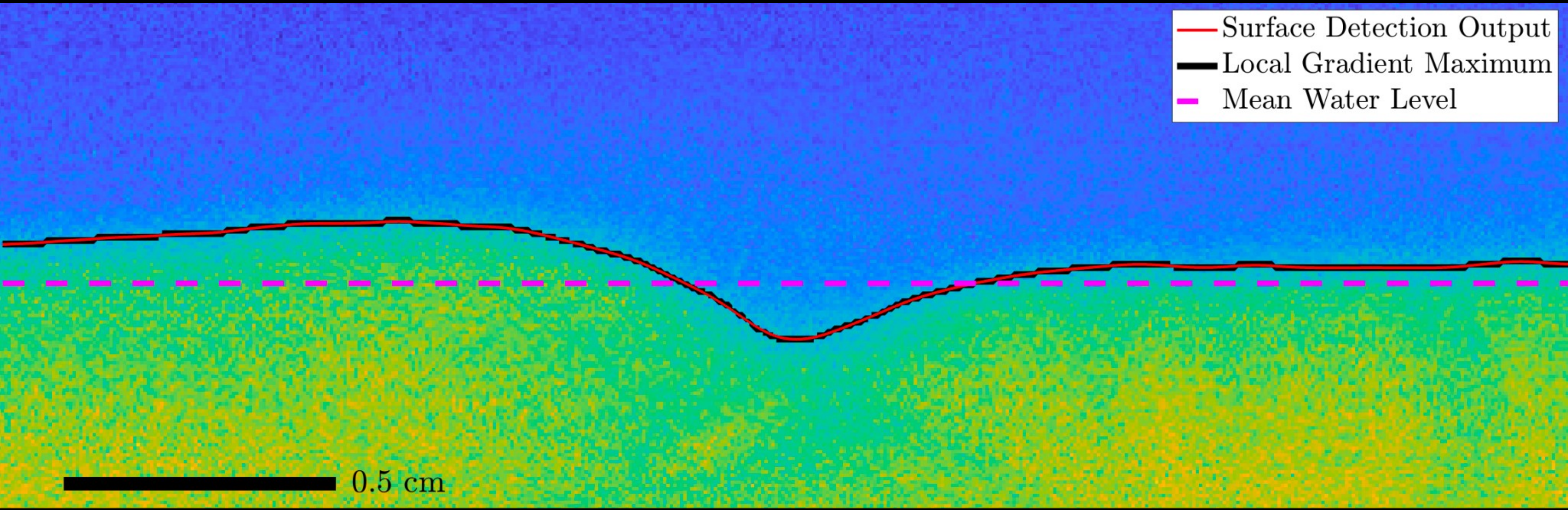
Minimum phase speed of linear gravity capillary waves 23 cm/s



slope

Longuet-Higgins (1989, 1993)

Shape is partially consistent with other observations of these lumps



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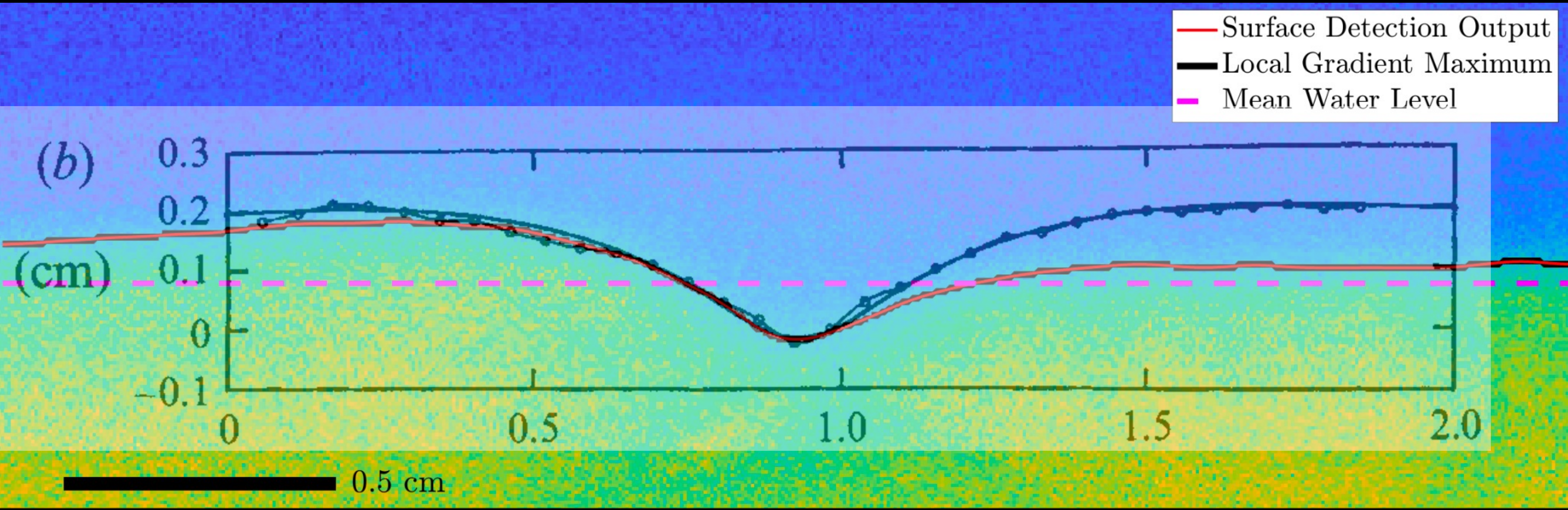
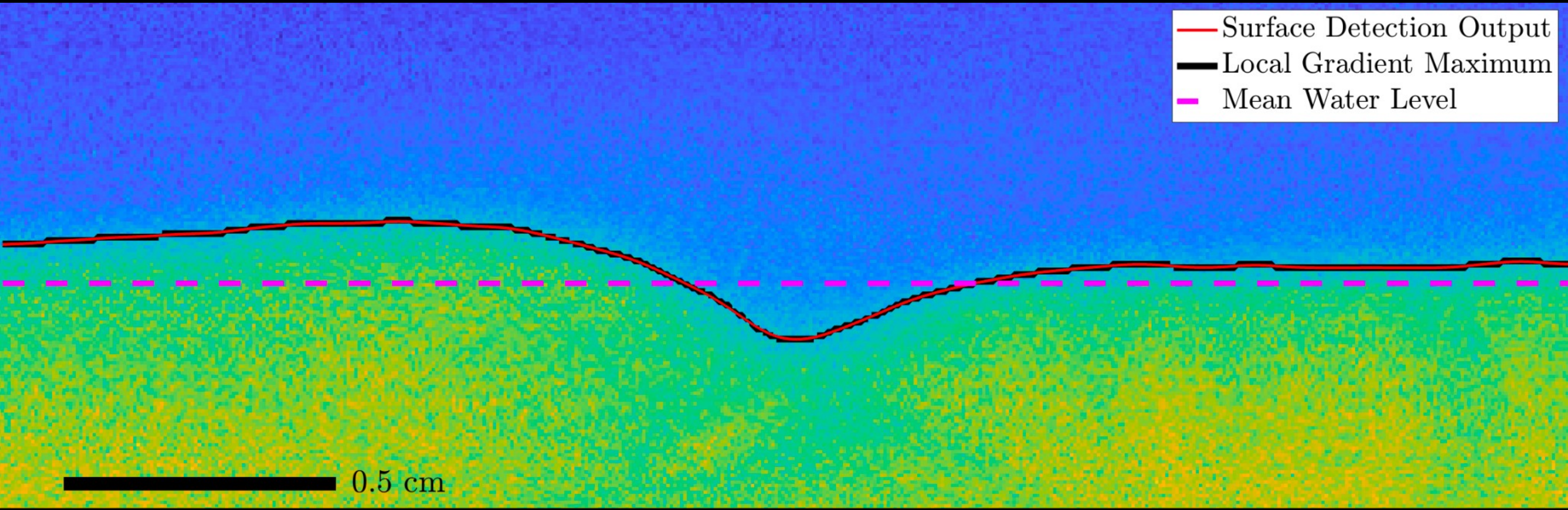
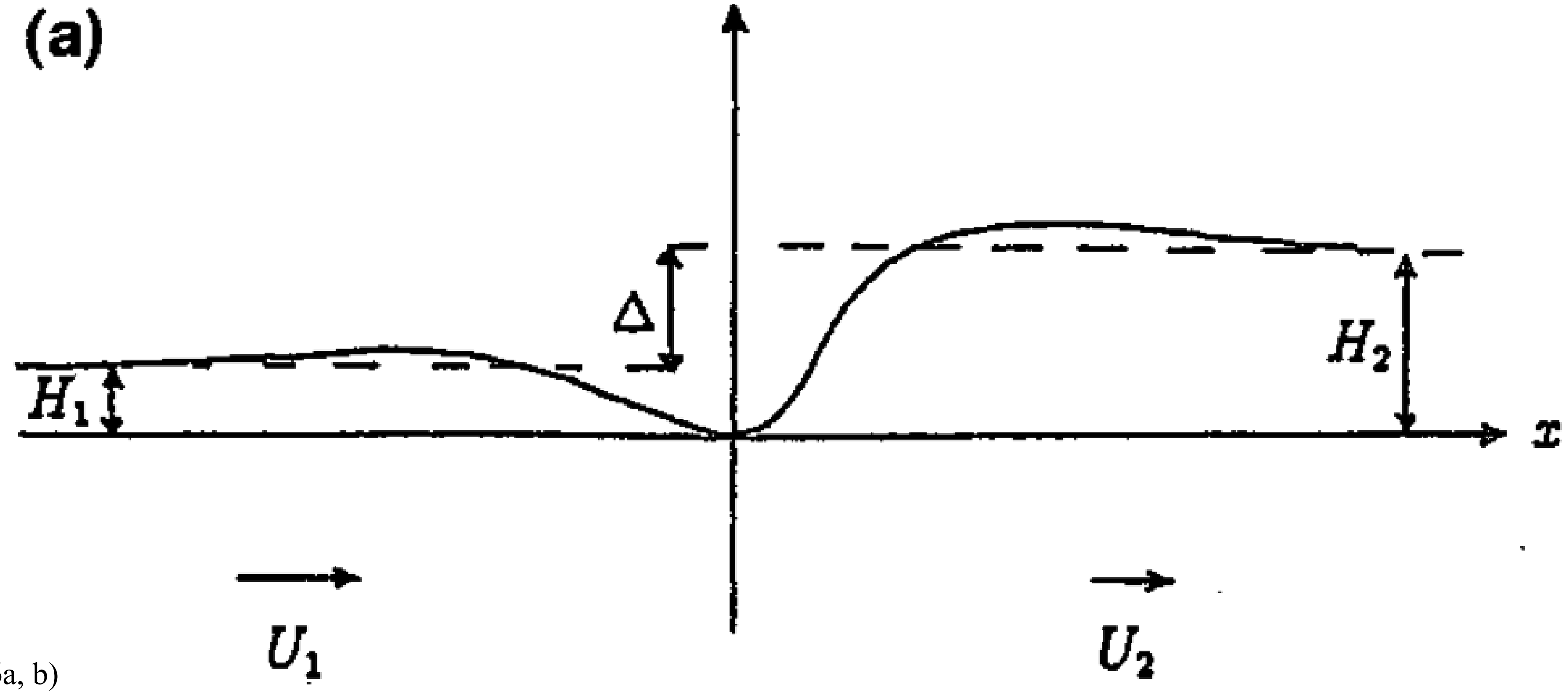
(Zhang 1995)



Asymmetry in mean water level



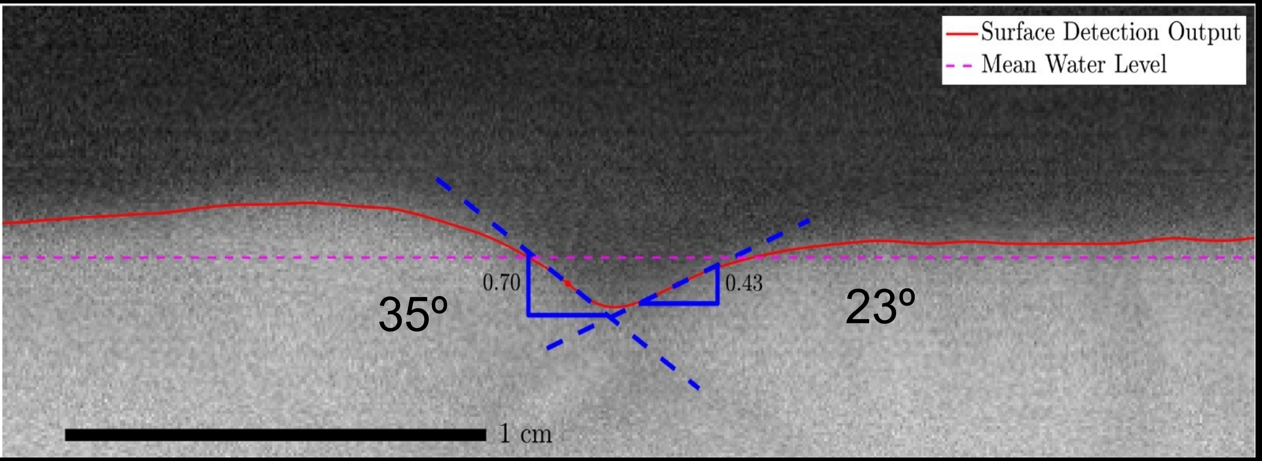
Change in mean water level corresponds to changes in U



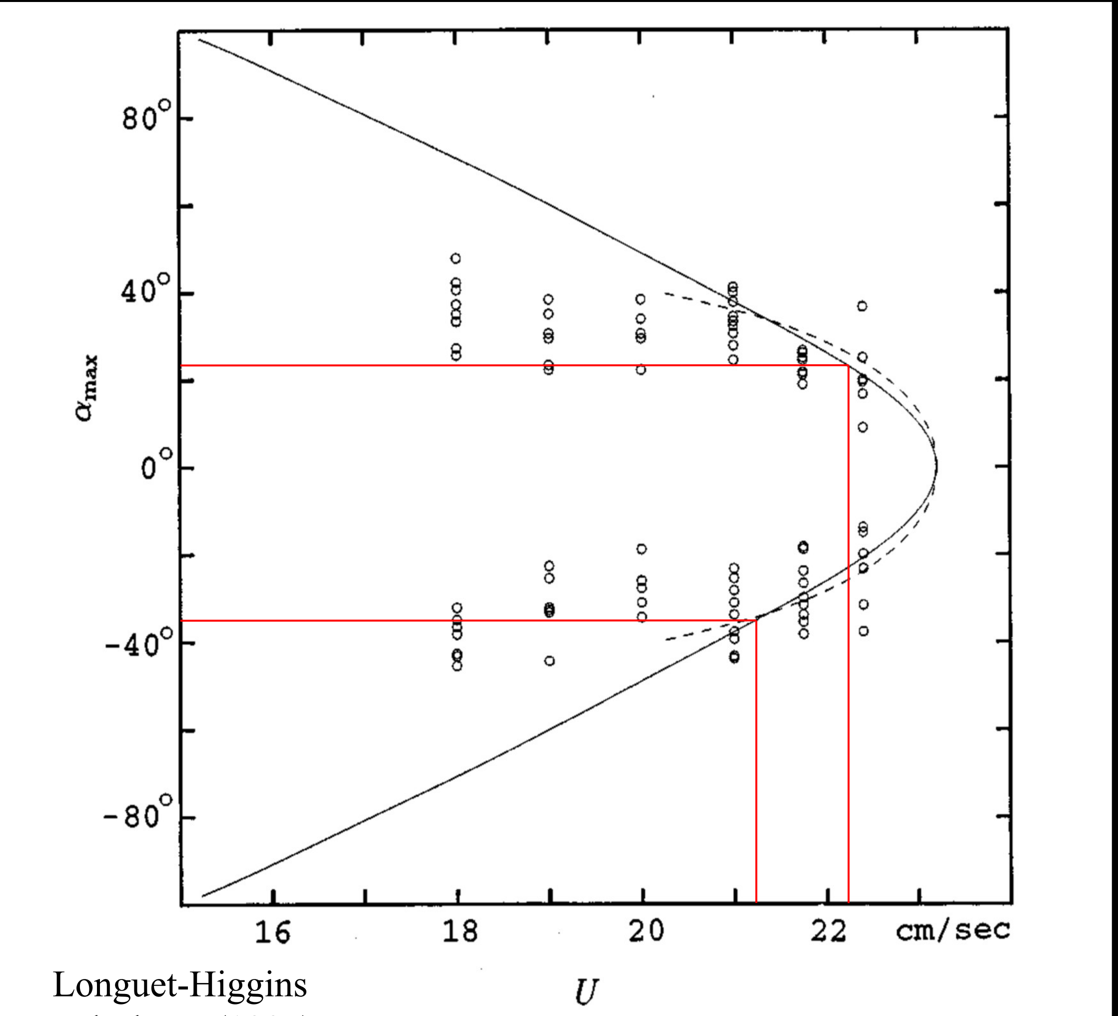
Longuet-Higgins (1996a, b)

Capillary "jumps": manifestations of non-uniform flow

Slopes imply velocity differences of about 1 cm/s



Compare with measurements of surface velocity?



Longuet-Higgins and Zhang (1997)

FIG. 8. Plot of α_{max} and α_{min} against the current speed U. The full curve corresponds to the theoretical calculations in Fig. 1, with $c = U$. Dashed curve is the asymptote (1.1).

Questions

What are the wave kinematics?

What is the impact of these wrinkles on roughness evolution?

How do these lumps change with different wind speeds?

PIV and an ensemble of experiments with different wind speeds will be examined.

Conclusions

Initial wrinkles on the water surface characterized by nonlinear compact waves of depression

Length scale ~1 cm

Asymmetric mean water levels correspond to current changes

Questions?

Lenain and Pizzo (2021)