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The structure and lifecycle of **stratified mixing by shear instability** in continuously forced shear flows

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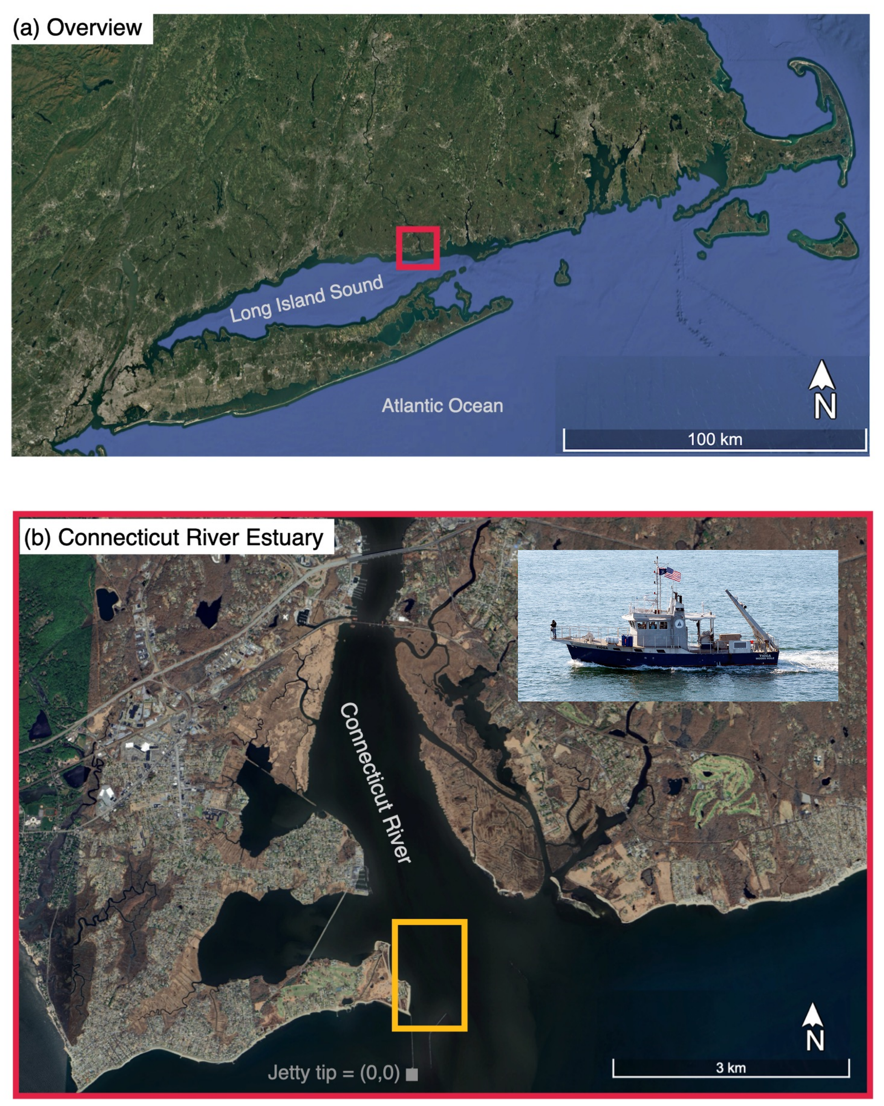
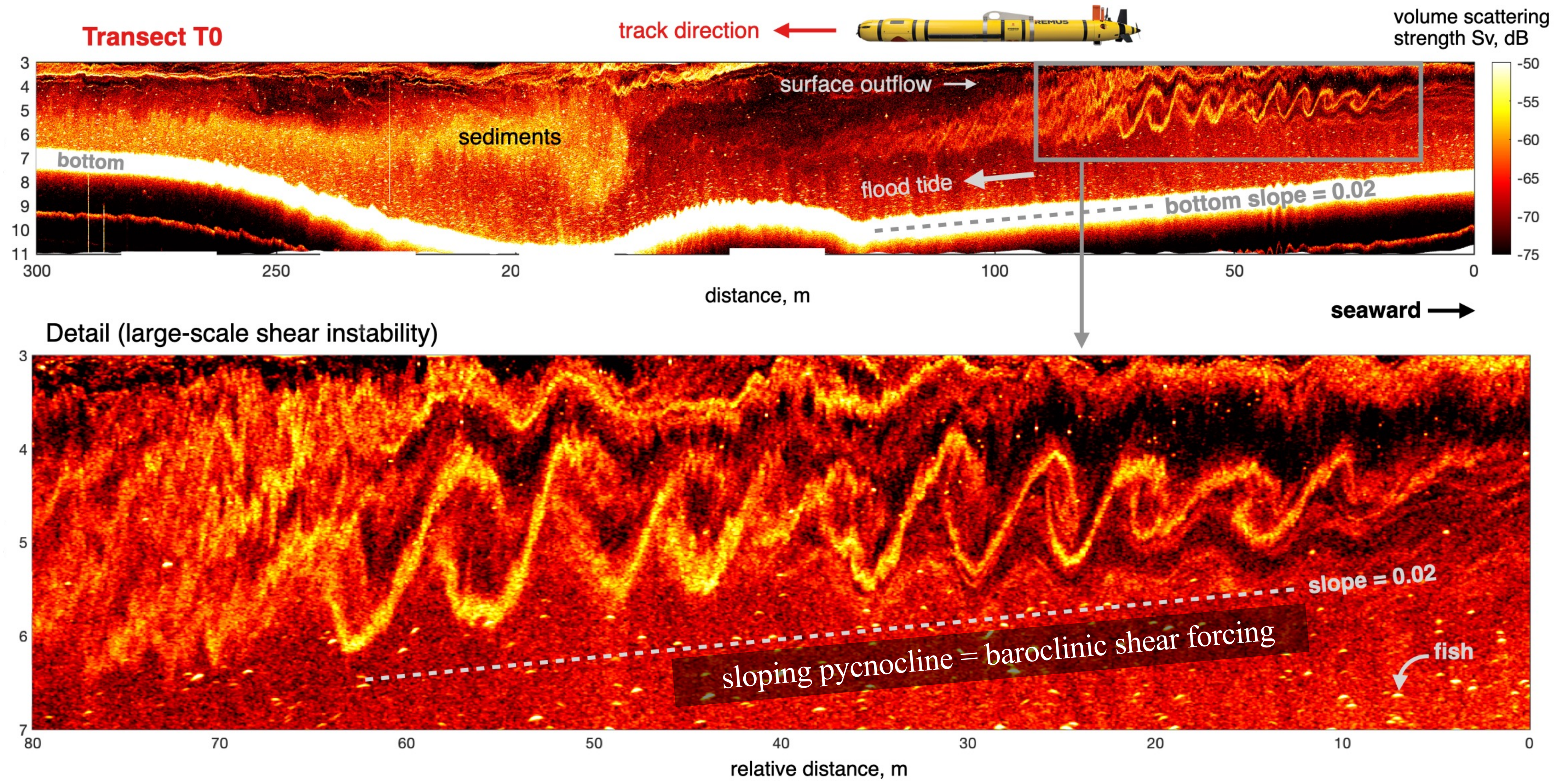
Find out more
Preprint:

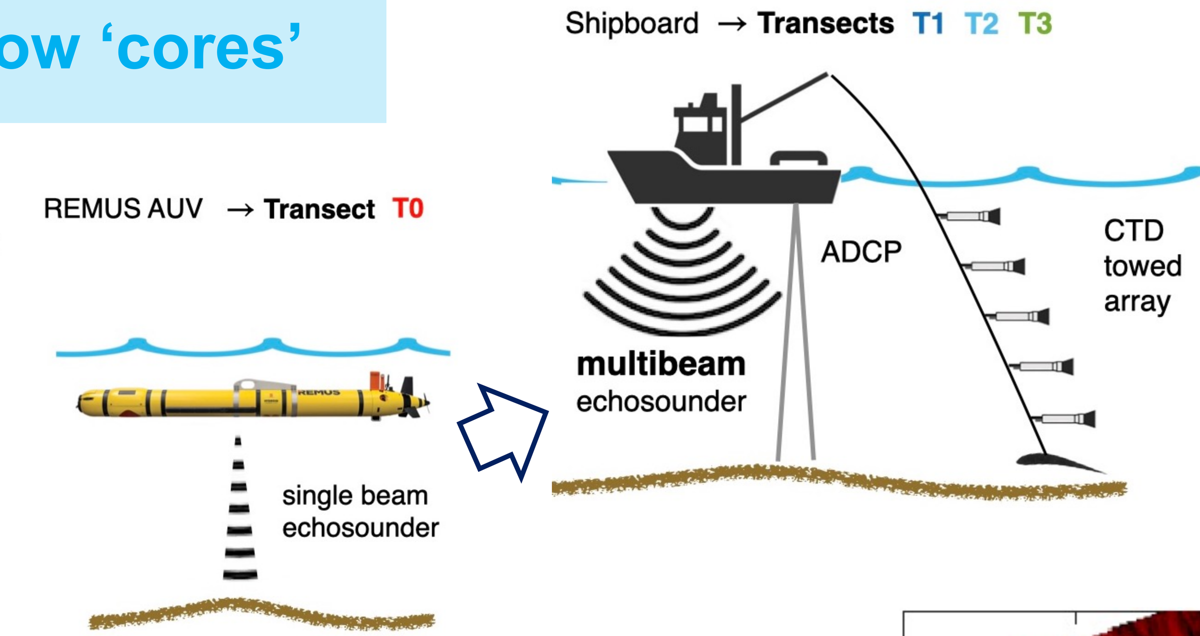
Observations in a salt wedge estuary: large shear instabilities mix in the 'braids' rather than in the billow 'cores'

Field site



Acoustic backscatter signal $\propto \log \chi_s$ = dissipation rate of salinity microstructure = turbulent mixing

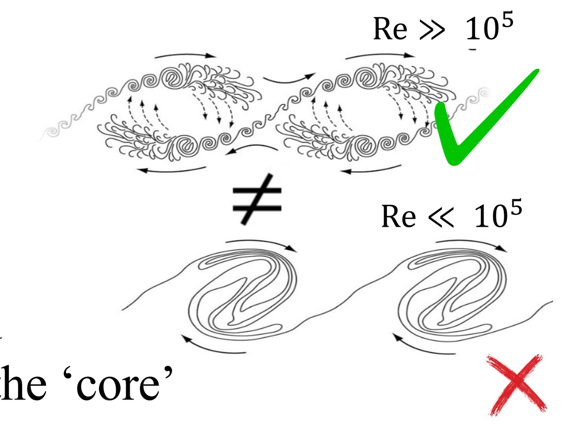




Reynolds number: $Re \sim 8\times10^5$

Richardson number: $Ri \sim 0.15$

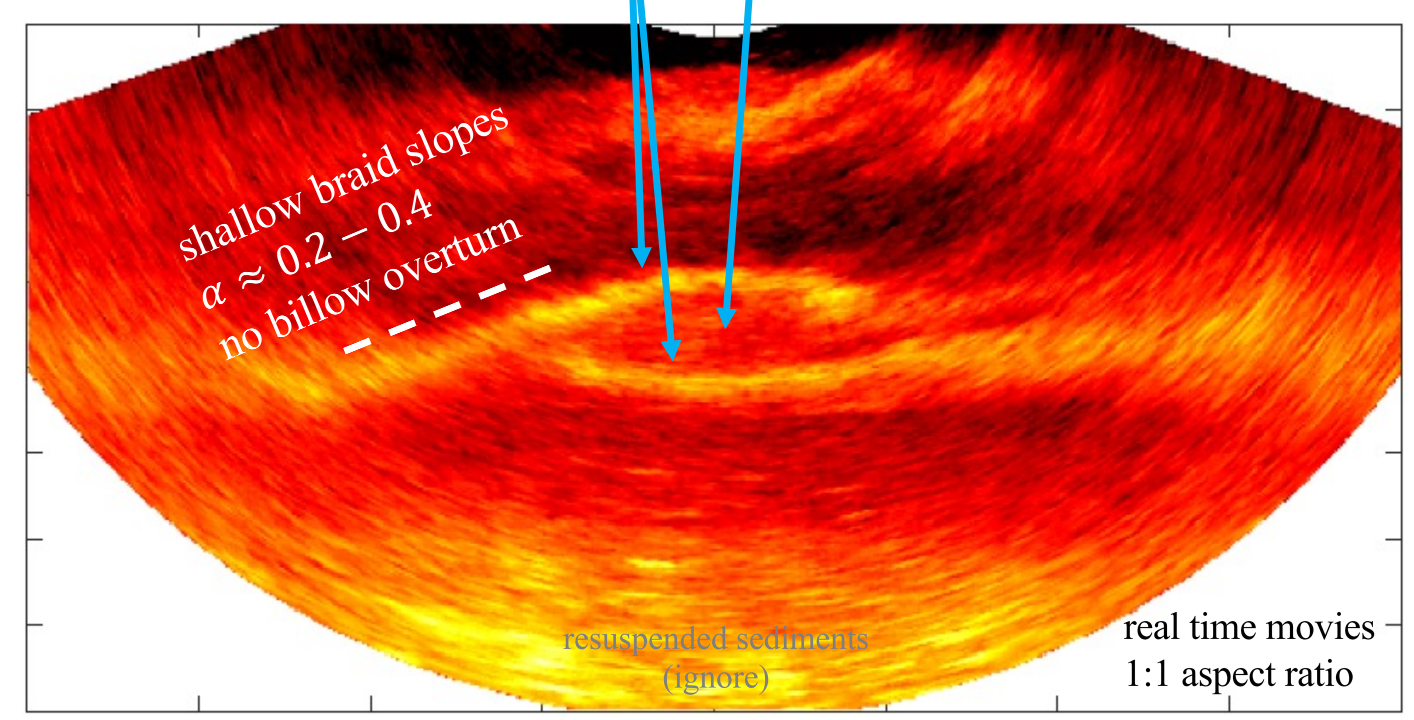
high χ_s mixing in the 'braid' or 'eyelid'
(χ is × 10^3 background levels)



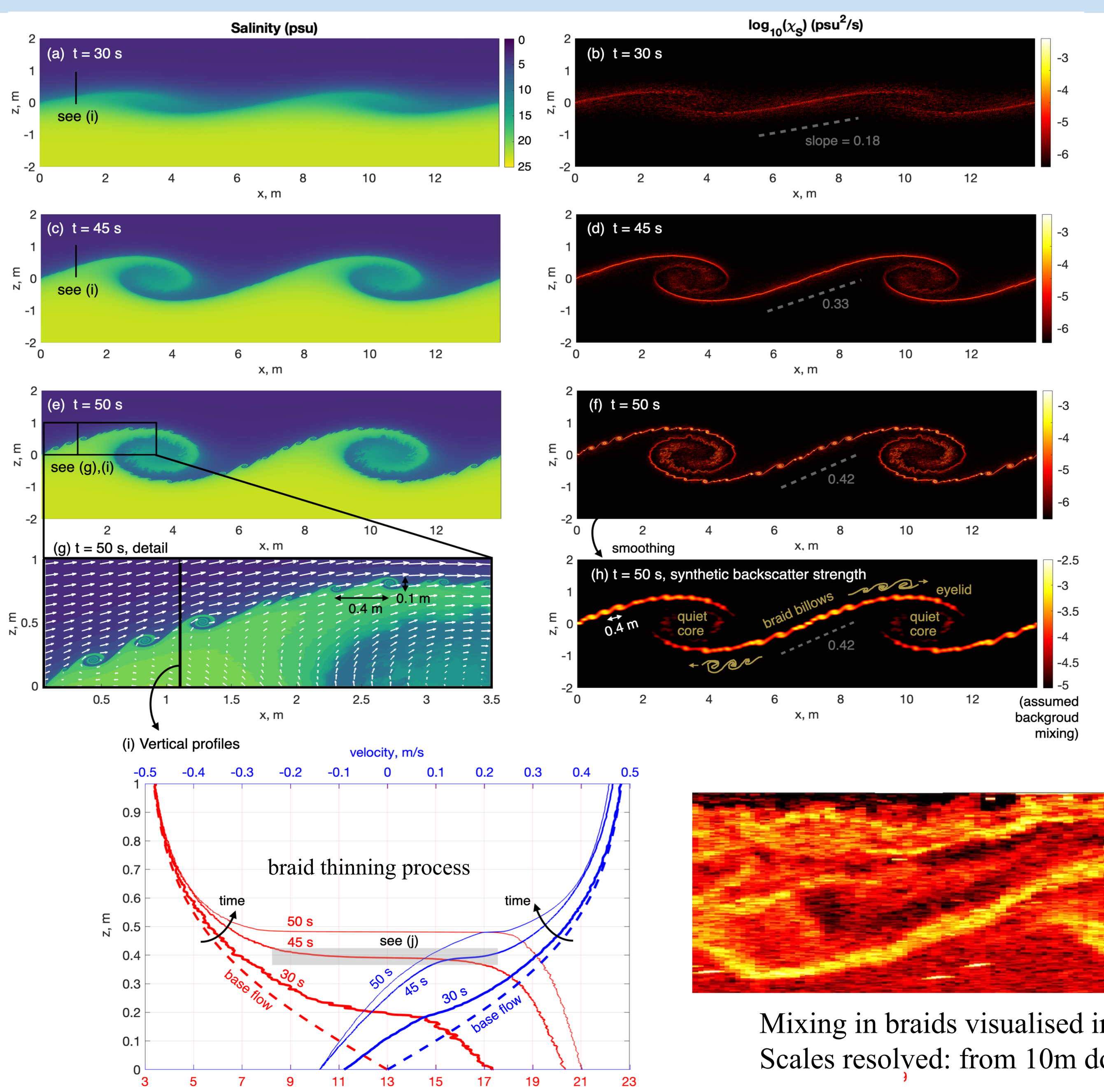
no elevated mixing in the 'core'

Single-beam echo-sounding provides useful 'transects' views but entangles spatial and temporal evolution

Multibeam echo-sounding reveals the **structure and lifecycle** of individual shear instabilities



Modelling: secondary shear instability triggers braid turbulence at high Reynolds number



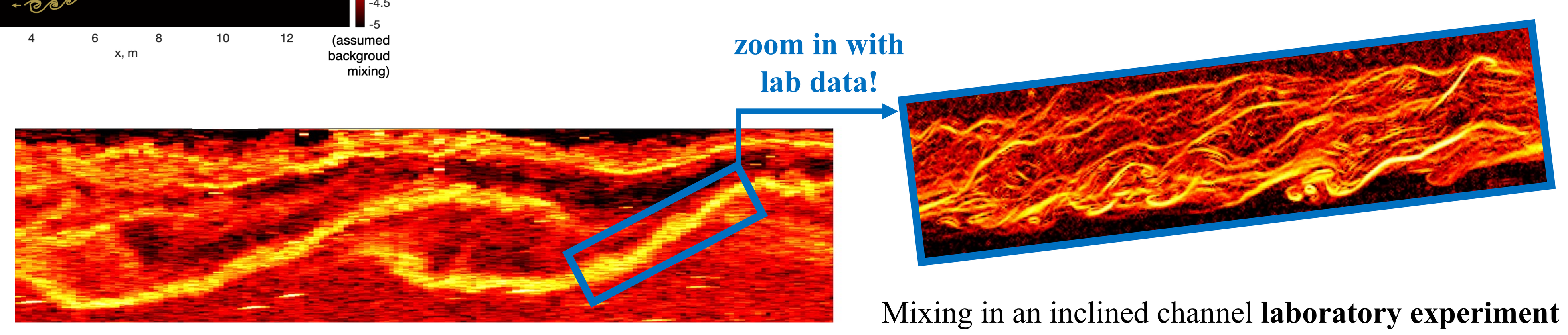
Two-dimensional direct numerical simulation at field-matched $Re = 8\times10^5$, $Ri = 0.15$, $Pr = 700$

Baroclinic shear production by the braid slope + strain compression
→ braid thins, shear increases and overcomes the stabilising strain
→ onset of secondary shear instability (SSI) possible if $Re \gtrsim 10^5$

At $Ri \gtrsim 0.1$, SSI can grow and outpace the primary instability
→ transition to **braid turbulence before billow overturn**

For more details, see recent theory paper:
Bouckley, Lewin & Lefauve (arXiv, 2026)

Structure of mixing below the resolution of observations?



Mixing in braids visualised in the field from the **echo-sounder**
Scales resolved: from 10m down to 1cm

Mixing in an inclined channel **laboratory experiment** reproducing 'braid turbulence' (baroclinic shear forcing)
Scales resolved: from 10cm down to 0.1 mm

Takeaways and implications

1. Shear instabilities under continuous shear forcing ($Ri \approx 0.10 - 0.15$) **mix along thin, sloping braids rather than through large overturns**
2. **Multibeam echo-sounding disentangles spatial and temporal evolution**, confirming shallow braid slopes $\alpha \approx 0.2 - 0.4$
3. At high $Re \gtrsim 10^5$, braid baroclinicity triggers **fast secondary shear instabilities and turbulence that pre-empt primary overturn**
4. A simple baroclinic production–dissipation balance **predicts dissipation rate ε and mixing rate χ_s** as a function of local slope α, thickness δ, shear S and buoyancy frequency N:
$$\varepsilon \approx 0.007\, \alpha \delta^2 S^3 \qquad \chi_s \approx 0.001\, (g\beta)^{-2}\, \alpha\, \delta^2\, N^2\, S^3$$
5. The above braid ε and χ_s predictions match the field data, and lab data reveal **extreme χ_s in sub-mm filaments, not overturns**
6. **Does this challenge assumptions in existing parameterisations** of turbulent mixing based on overturns, e.g. based on Thorpe scales?

Multiscale approach combining **observations, modelling** and **lab** data