Internal Solitary Waves with shear: beyond DJL theory

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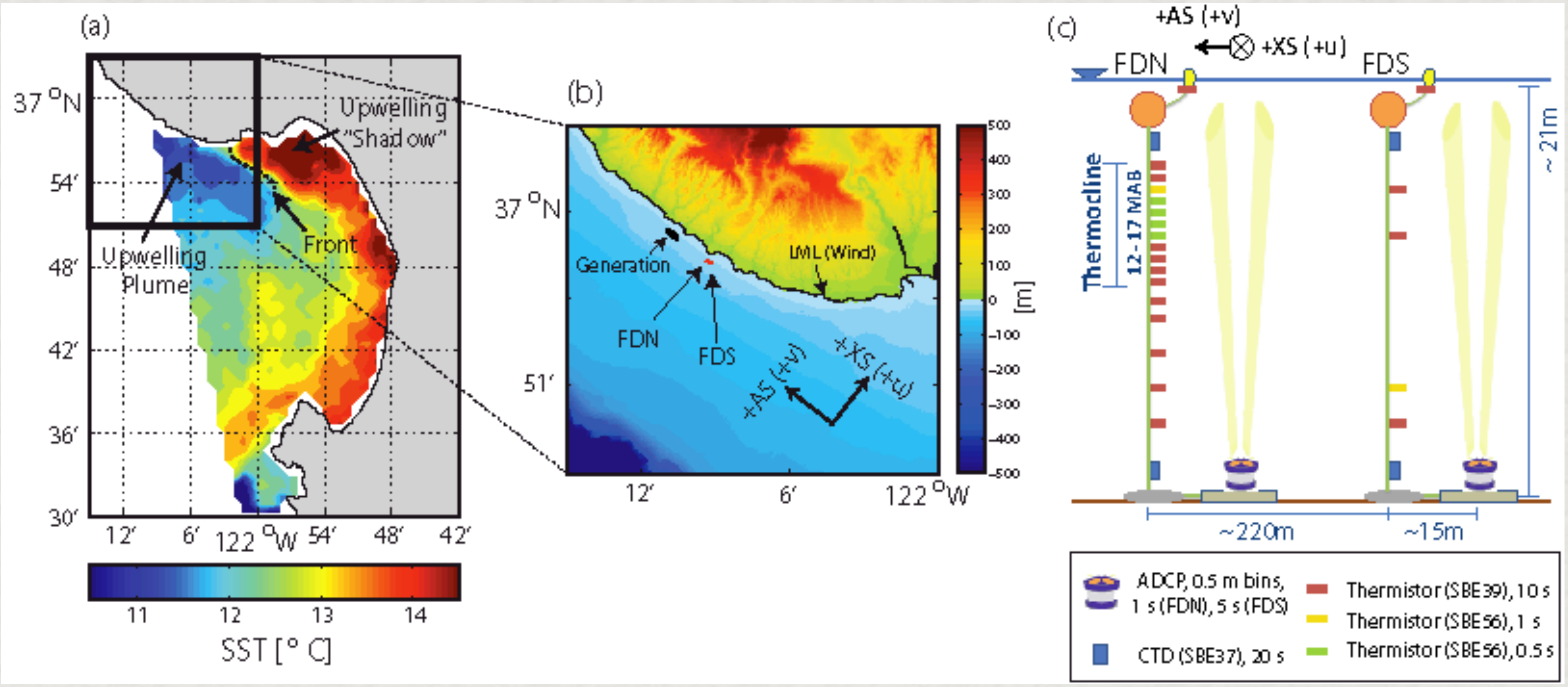
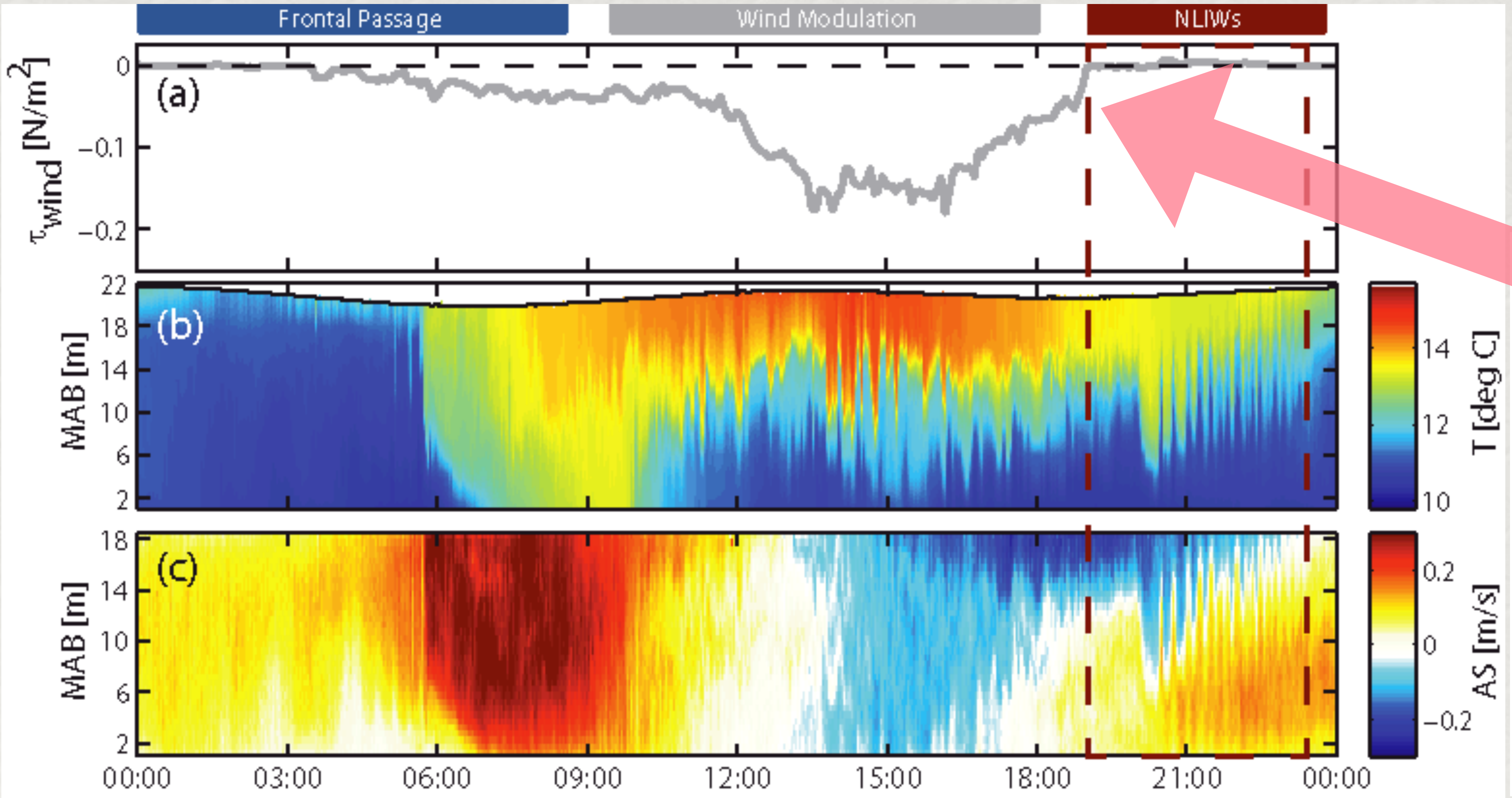
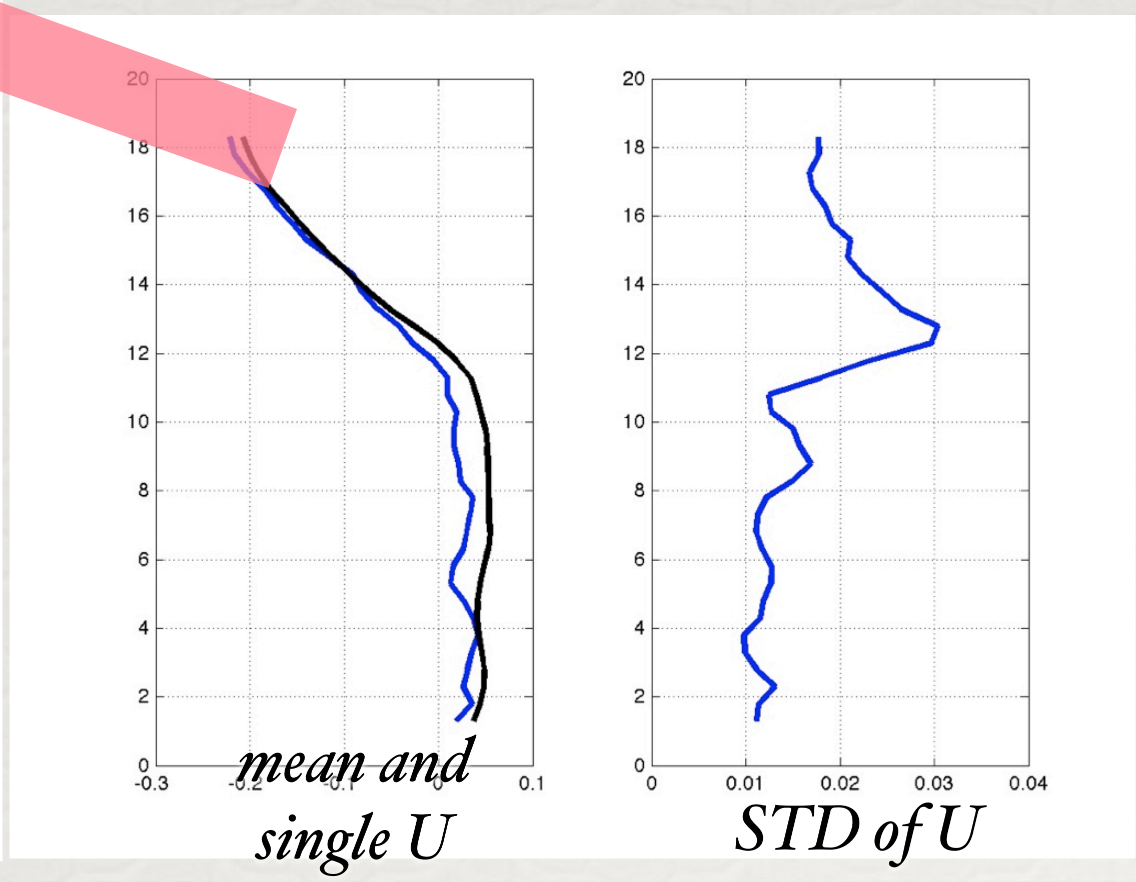


- Measurements in Monterey Bay suggest that solitary-like wave trains exist in the presence of a strong background current
- The complexity of the field situation meant we wanted to return to a more controlled setting to understand what is going on.

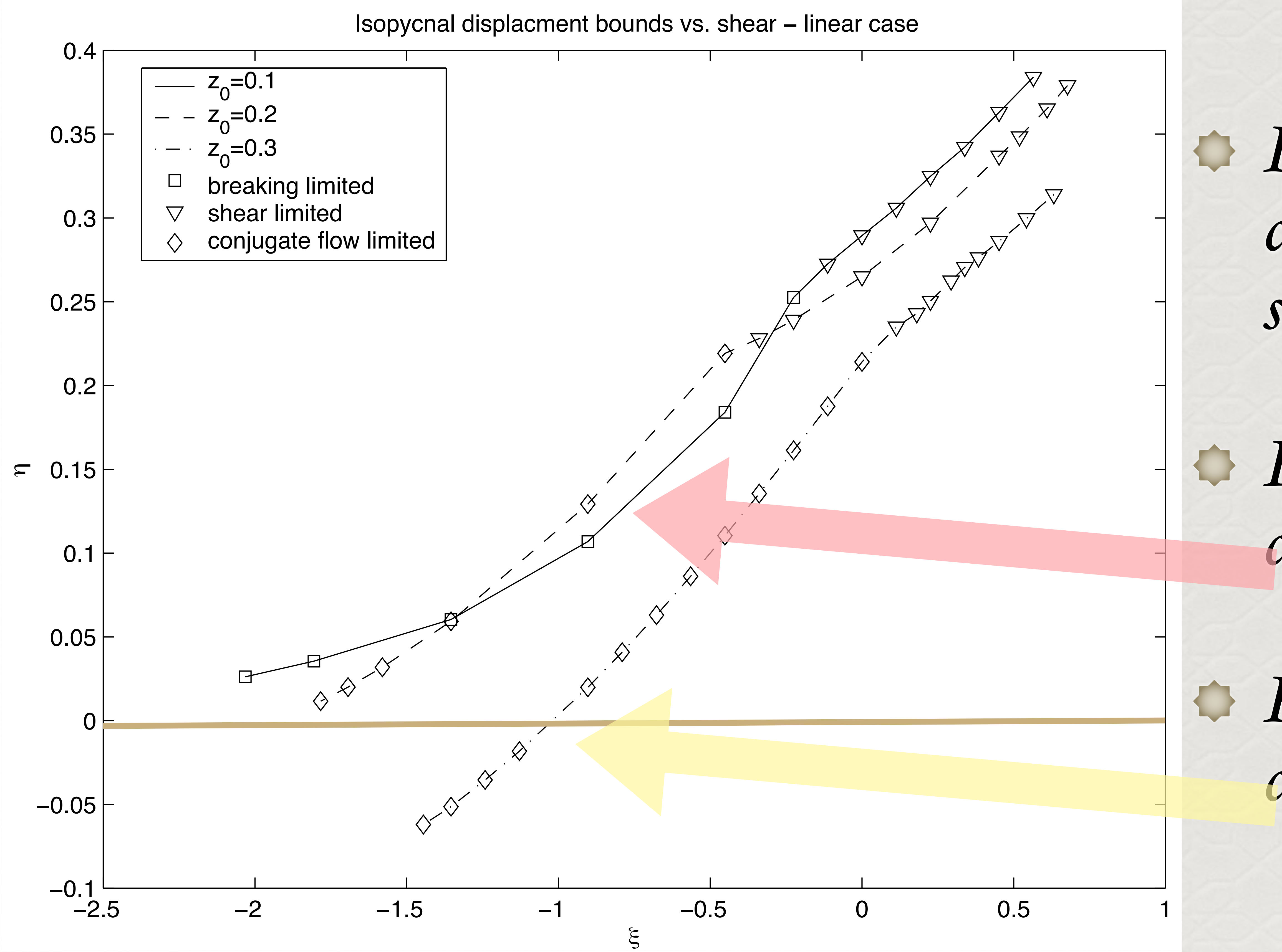




- Internal Solitary-like Waves (ISWs) can be described by various theories including the DJL equation which is formally equivalent to the full stratified Euler equations.
- $$\nabla^2\eta + \frac{U_z(z-\eta)}{(U(z-\eta)-c)}\left[1-\left(\eta_x^2+\left(1-\eta_z\right)^2\right)\right] + \frac{N^2(z-\eta)}{(U(z-\eta)-c)^2}\eta = 0$$
- In the presence of background shear these are invalidated when the background velocity matches the propagation speed (i.e. a critical layer forms).
- There are fixes in the literature based on perturbation theory, but in practice computation of exact ISWs fails.
- Background shear is subtle and even when it doesn't make theory fail it can modify waves a considerable amount, as the next slide shows

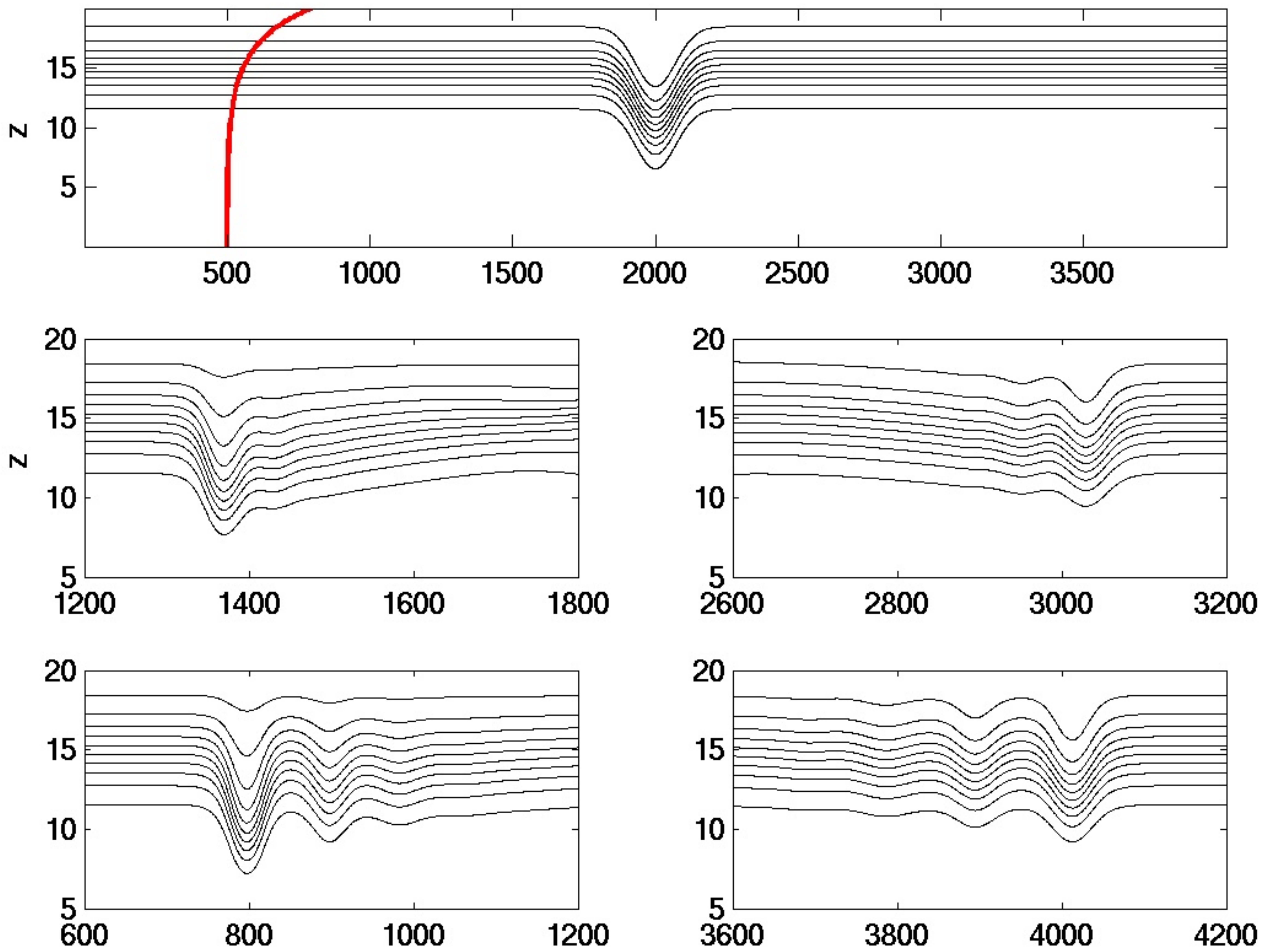
Fully nonlinear ISWs with Background Shear

Stastna and Lamb, PoF, 2002

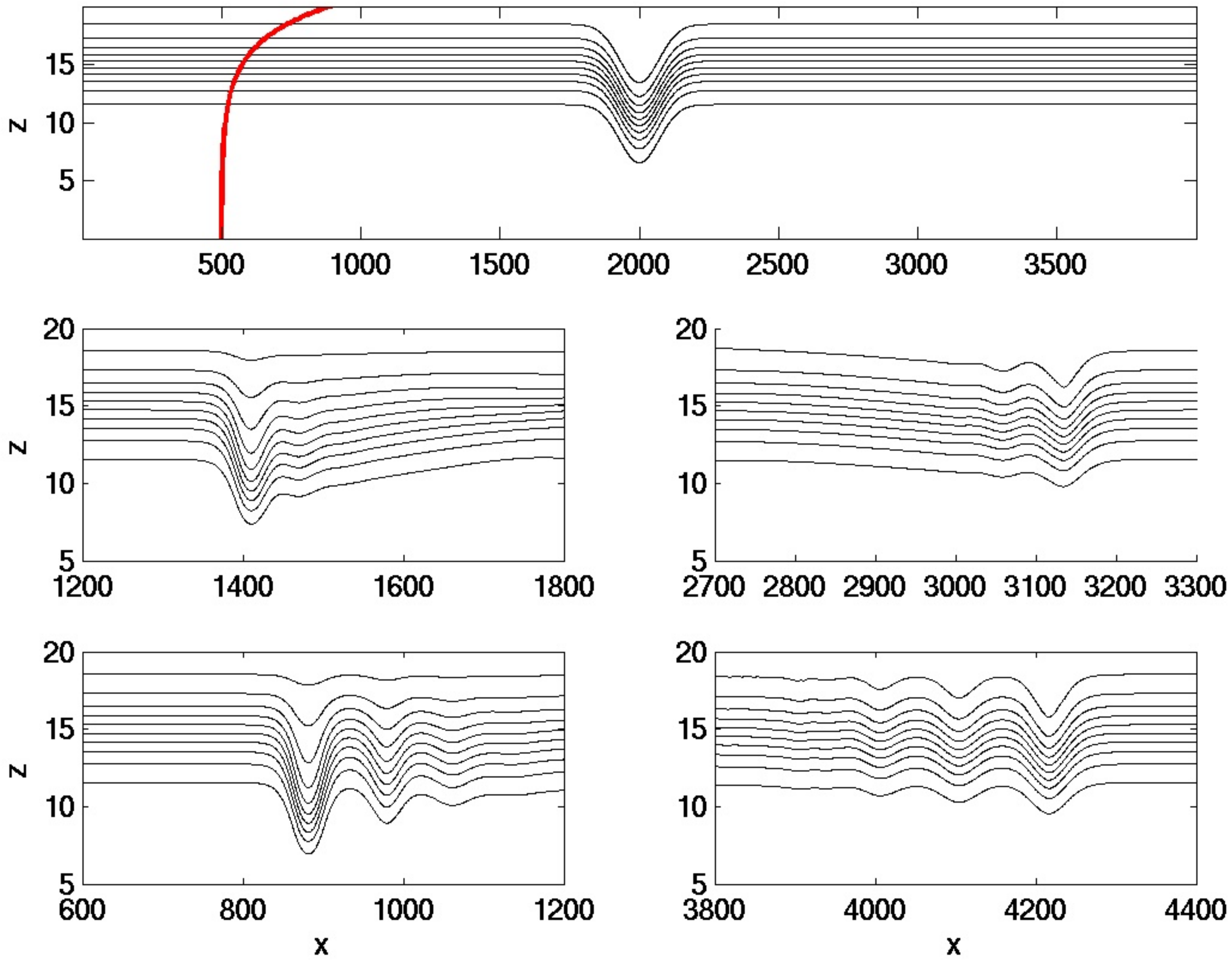


- *Fully nonlinear ISWs can be solved for up to some limiting amplitude*
- *Limiting amplitude changes as U(z) changes*
- *Polarity of ISWs can change as U(z) changes*

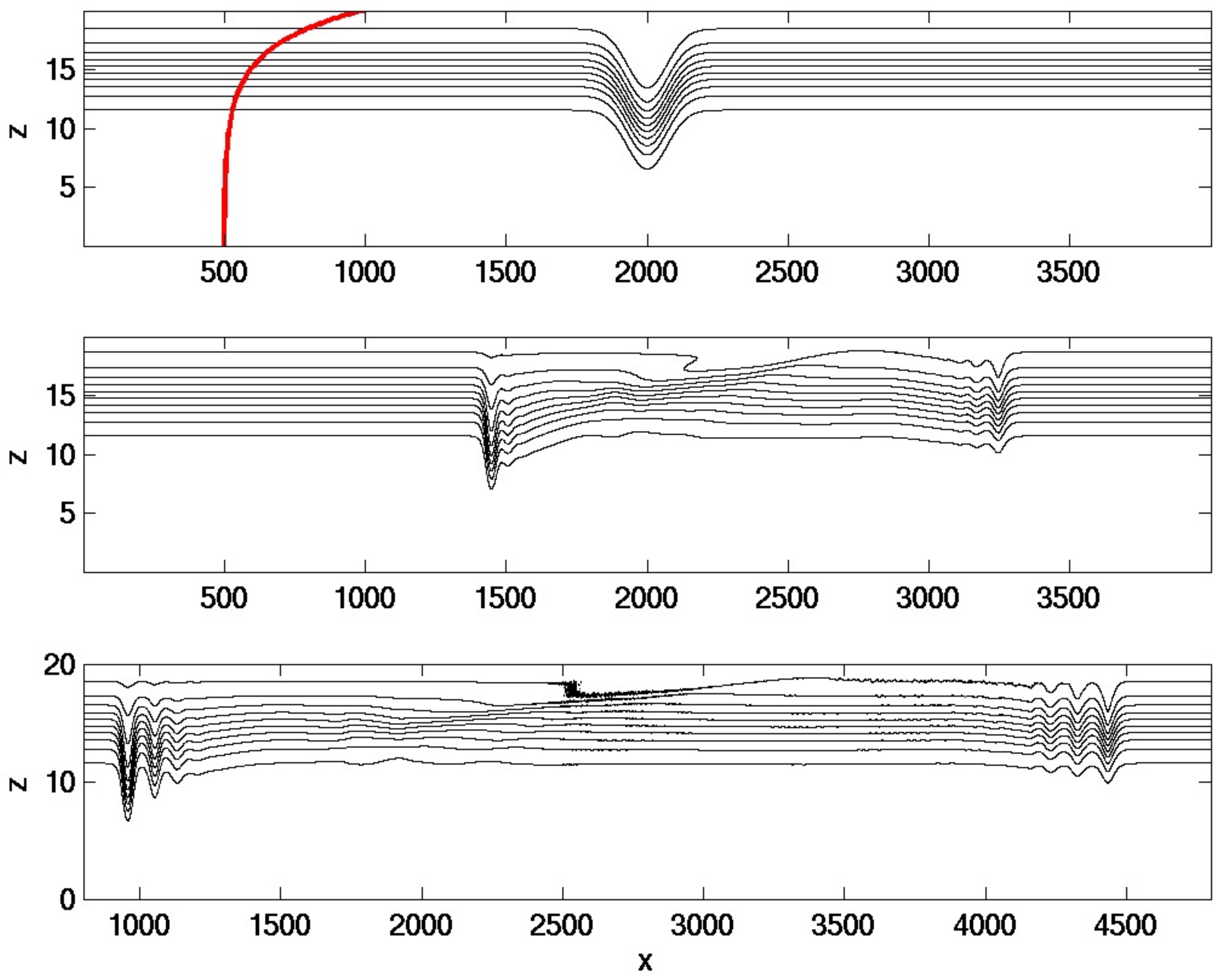
- In a series of numerical experiments we returned to the classical stratified adjustment problem with shear to probe the evolution of large amplitude waves in the presence of a background current that was taken to have a surface-trapped, exponential form.
- In particular we wanted to know if coherent waves form (solitary or not) and whether they separate from their tail (and the form of this tail).
- The simulation is in a periodic domain allowing us to see if waves survive collisions, and how they interact with even stronger shear associated with the tail.



Coherent ISWs form in both directions

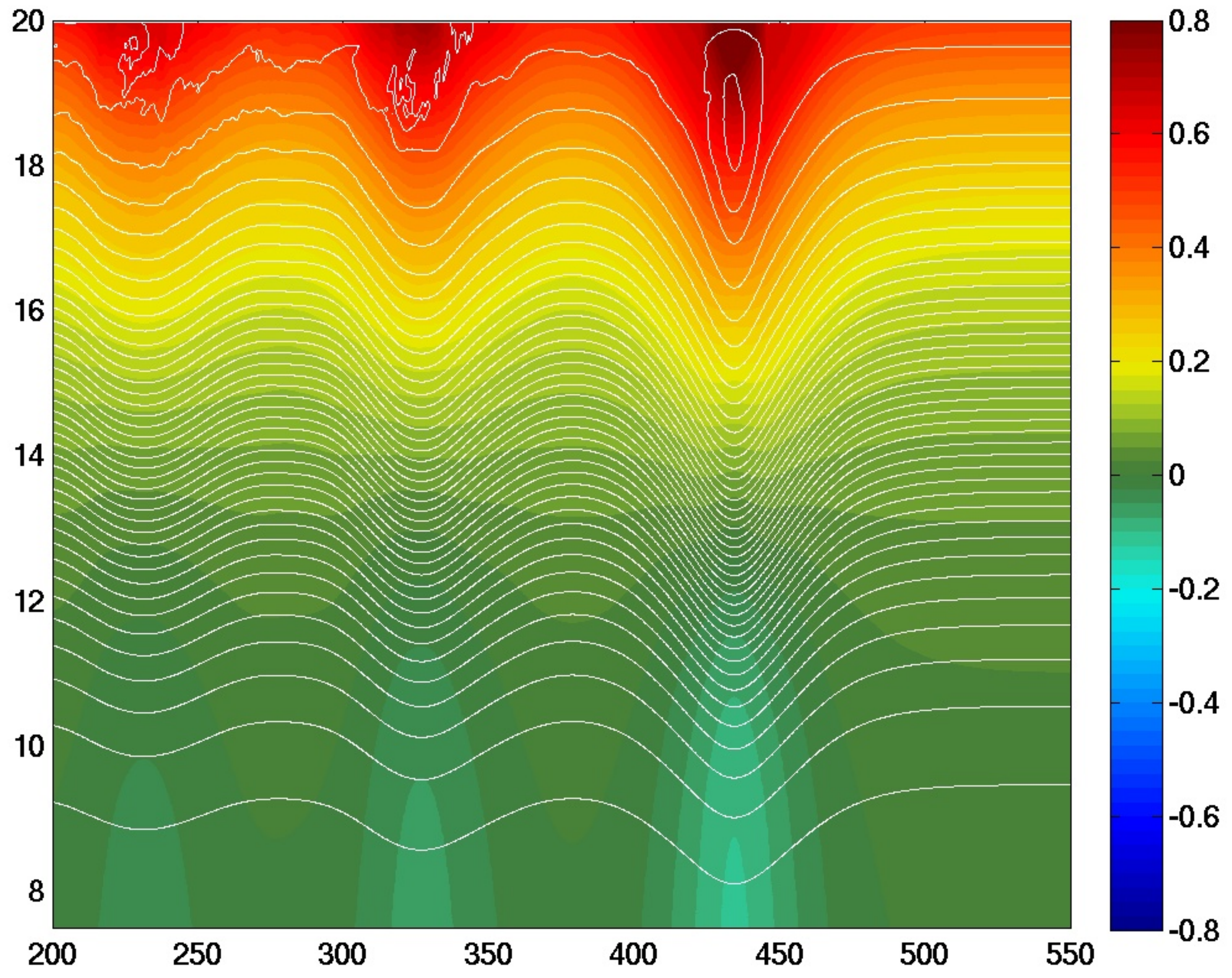


Stronger Current: Coherent ISWs still form in both directions but asymmetry is more prominent

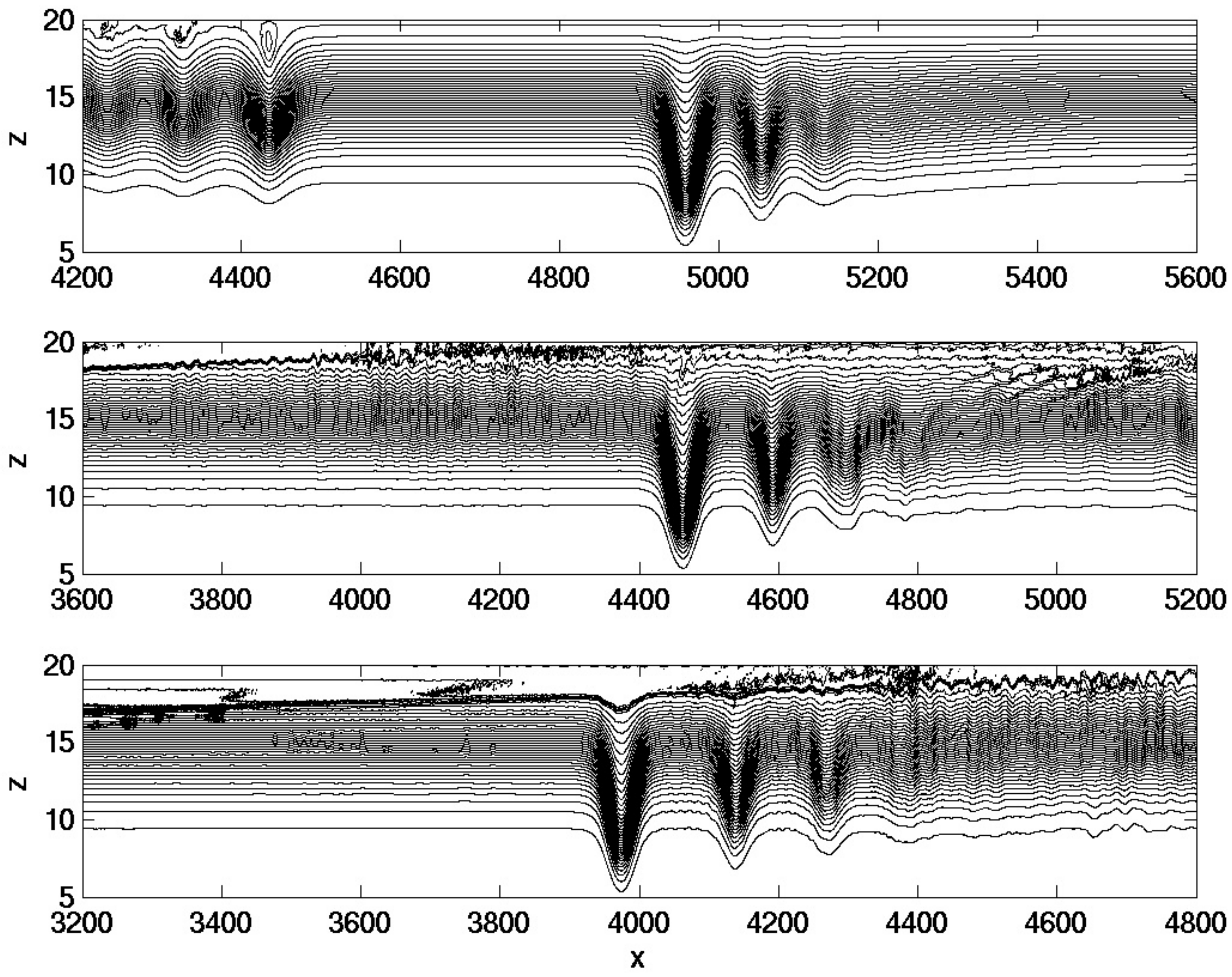


Strongest Current: Again coherent ISW trains but tail appears attached to rightward propagating waves. Short length scale shear instability observed

Horizontal component of velocity field with overlaid isopycnal for rightward train. Clear trapped cores

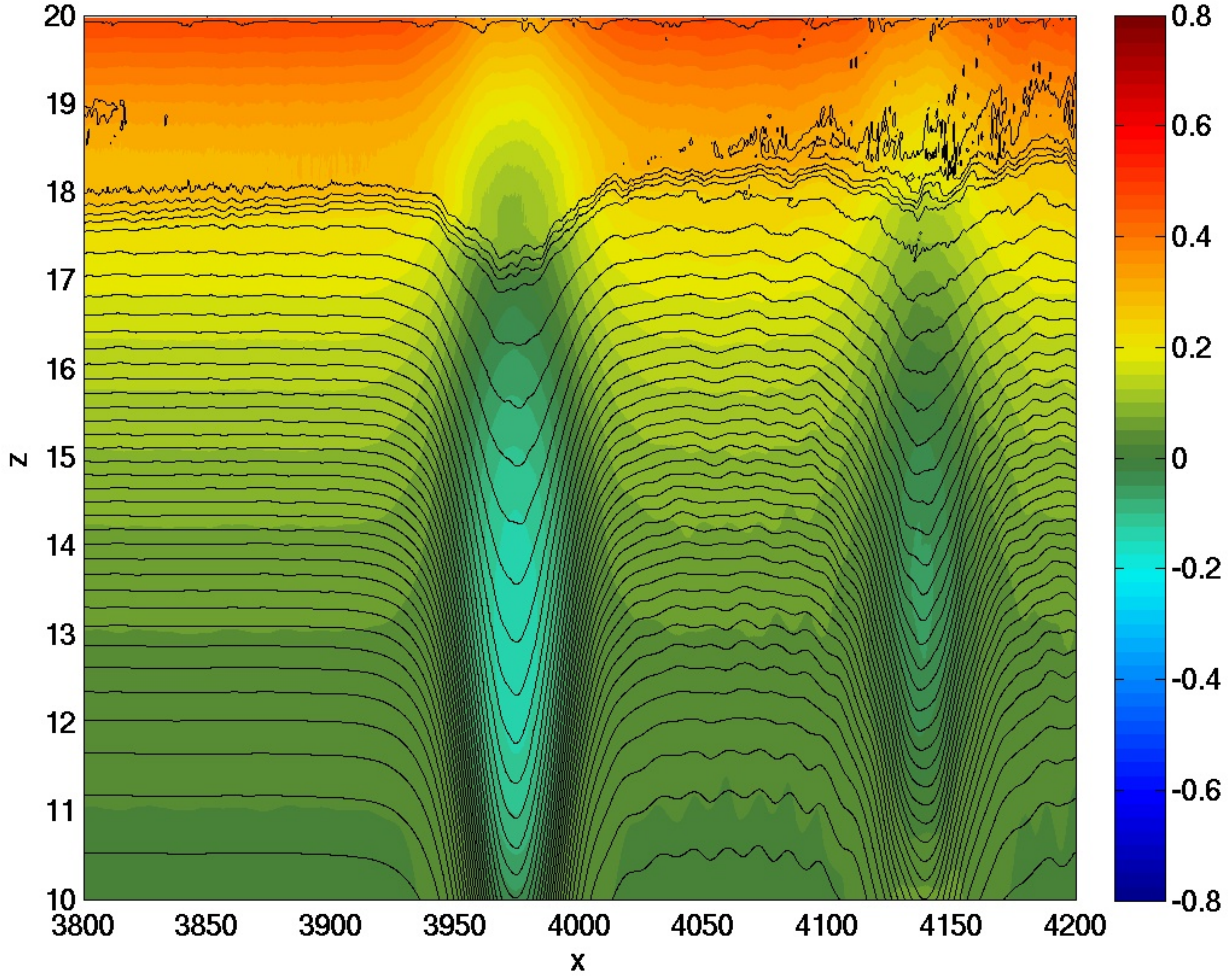


Leftward wave train after passing through periodic boundary. Will ineract with rightward wave train, but more importantly with the tail.

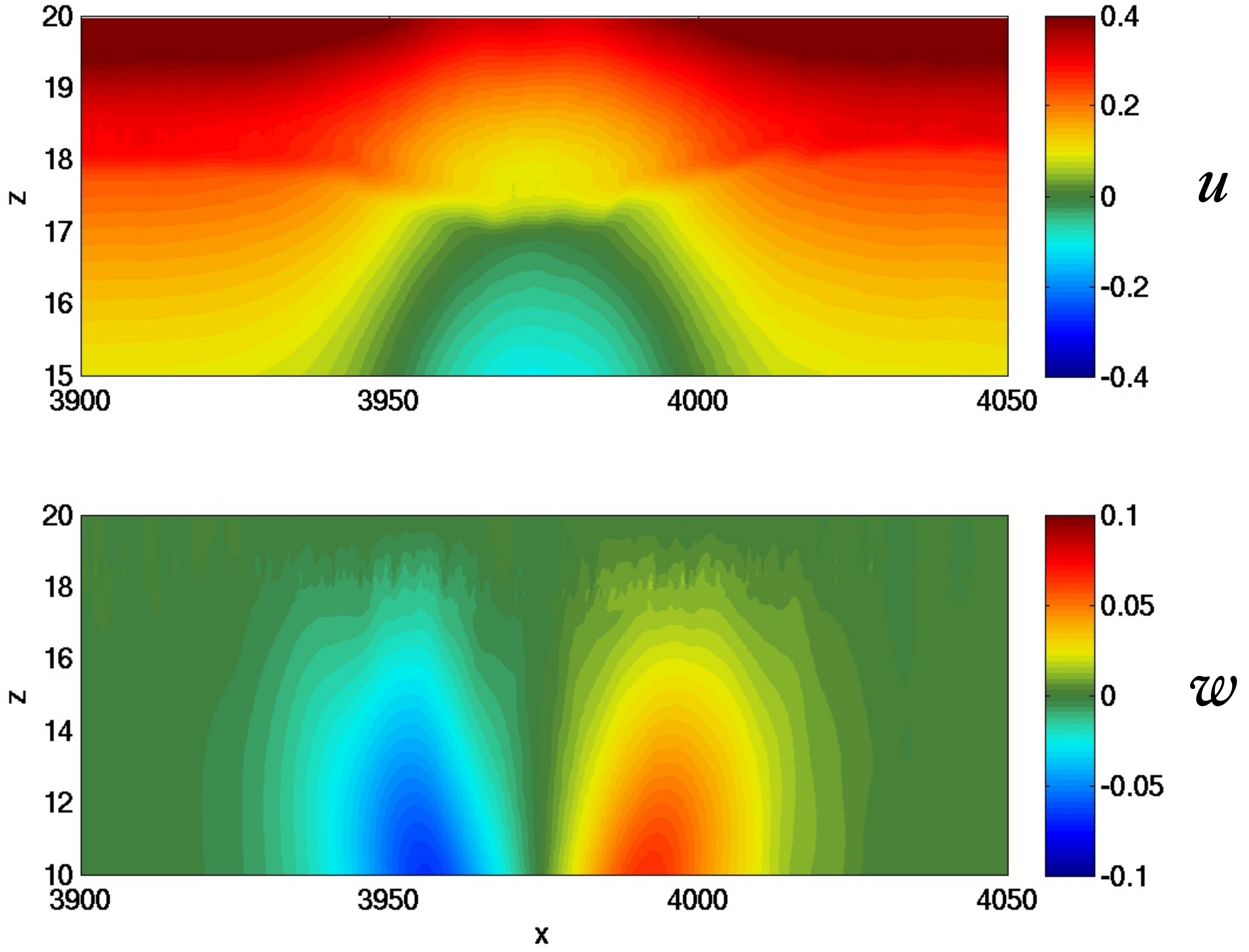


The tail is a high shear region allowing us to observe the natural evolution in a high shear region

Leftward wave train after passing high shear tail. Horizontal component of velocity is positive while wave propagates to the left suggests this is not a critical layer region.



u and w in high shear region.
u has large scale structure while w is mostly associated with shear instability.



- Lots remains to do; resolution tests; wave coherence and at least some 3D simulations (the high resolution needed to accurately resolve the near surface region is already expensive in 2D).
- The parameter space is quite rich, so while I chose one interesting aspect to show, we have looked at other parameter regions in which it is possible to probe the limits of the DJL a bit more closely.
- The upshot is that naturally occurring ISWs are more coherent than theory would suggest.