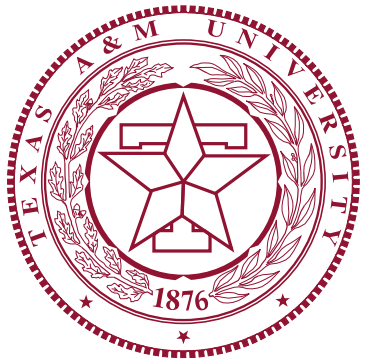
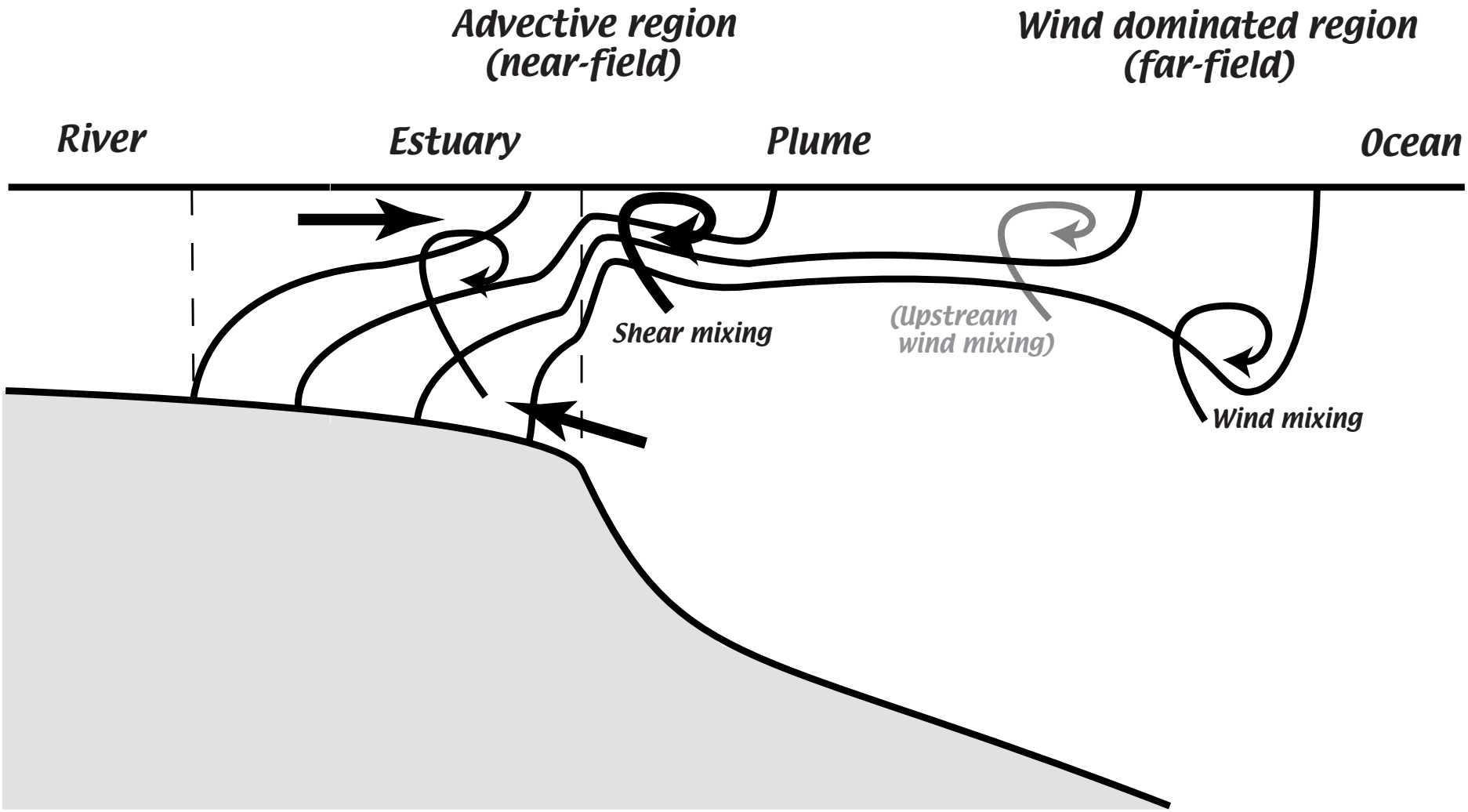
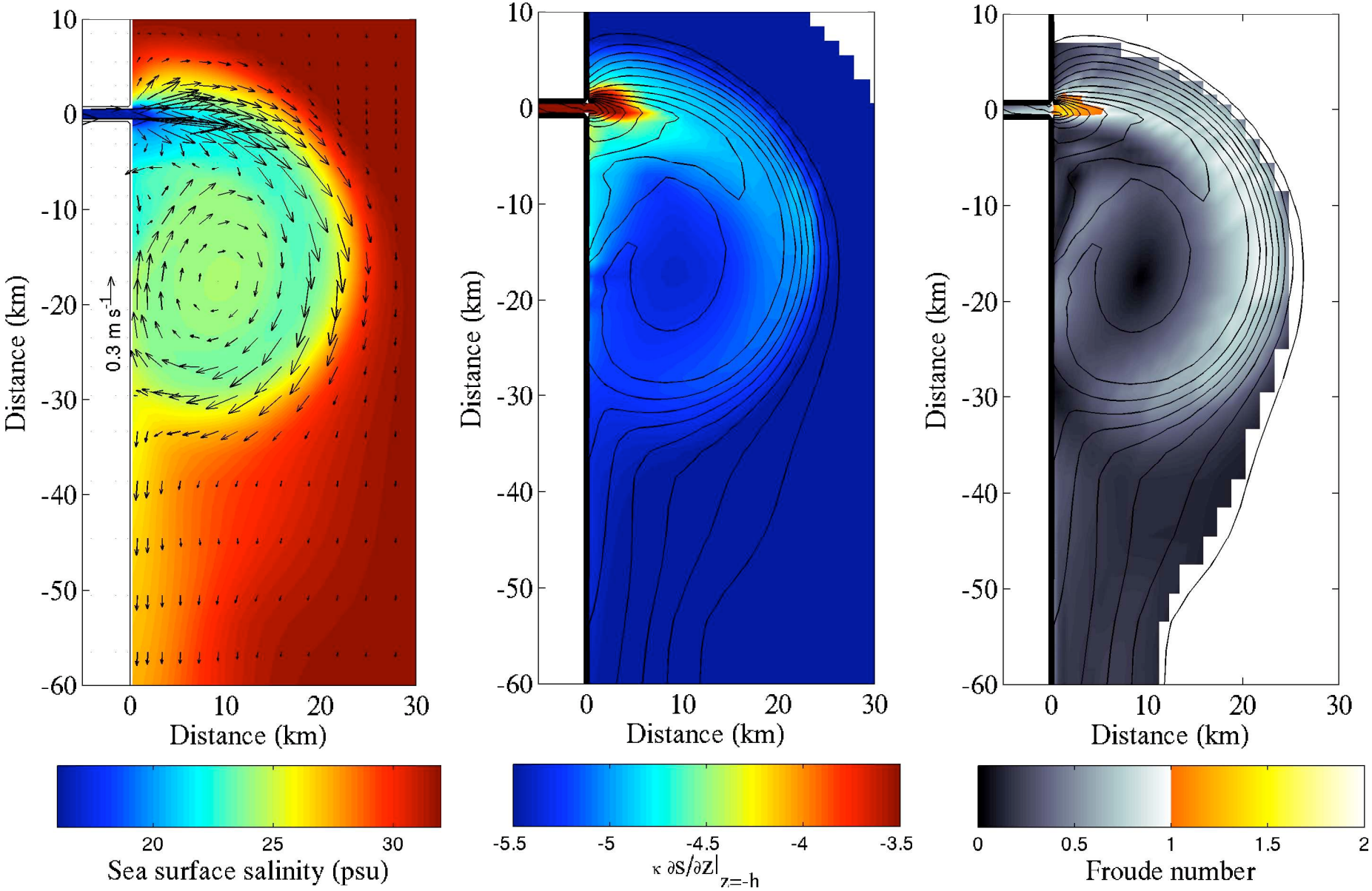
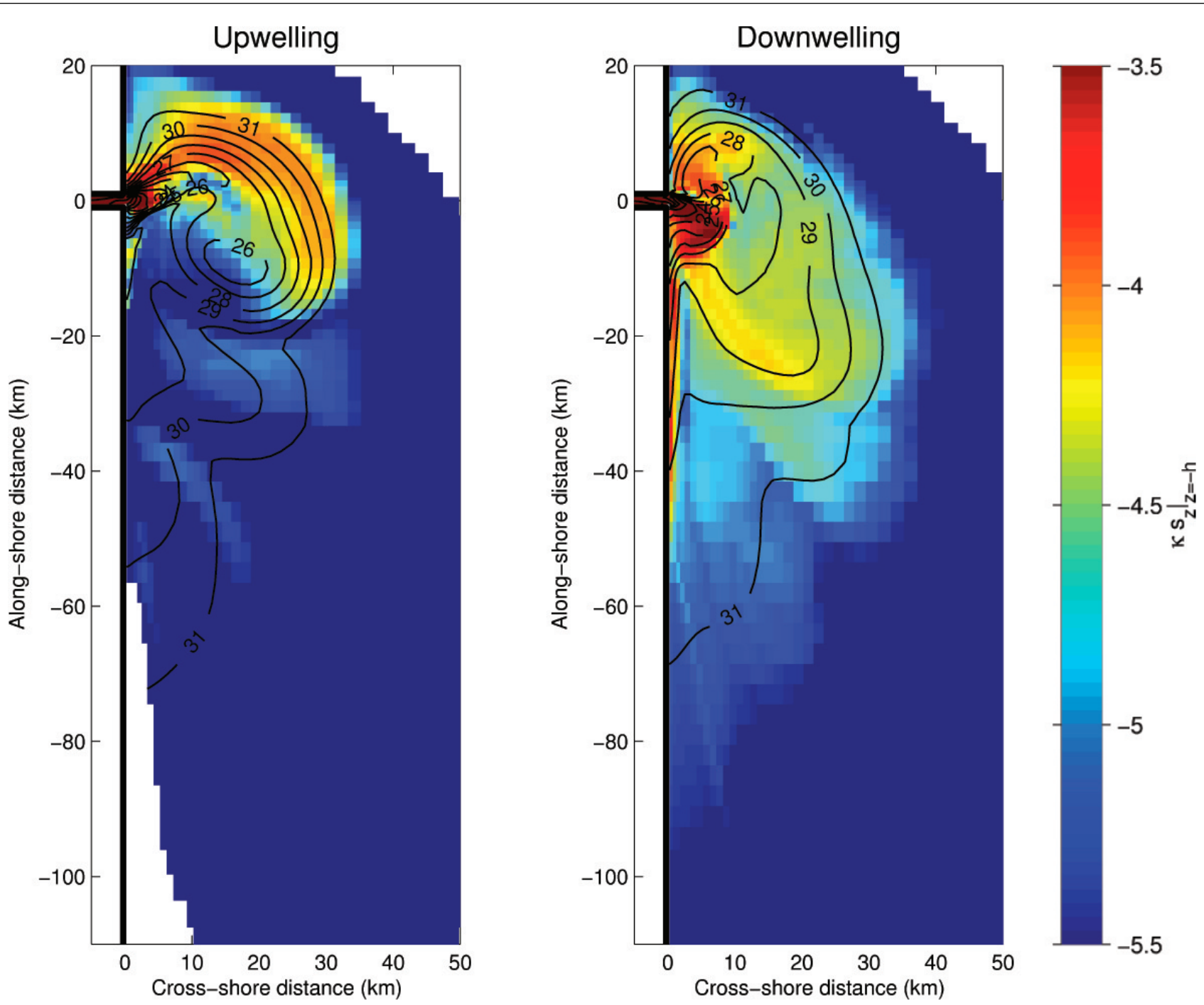
Water mass modification in near-field river plumes

Rob Hetland

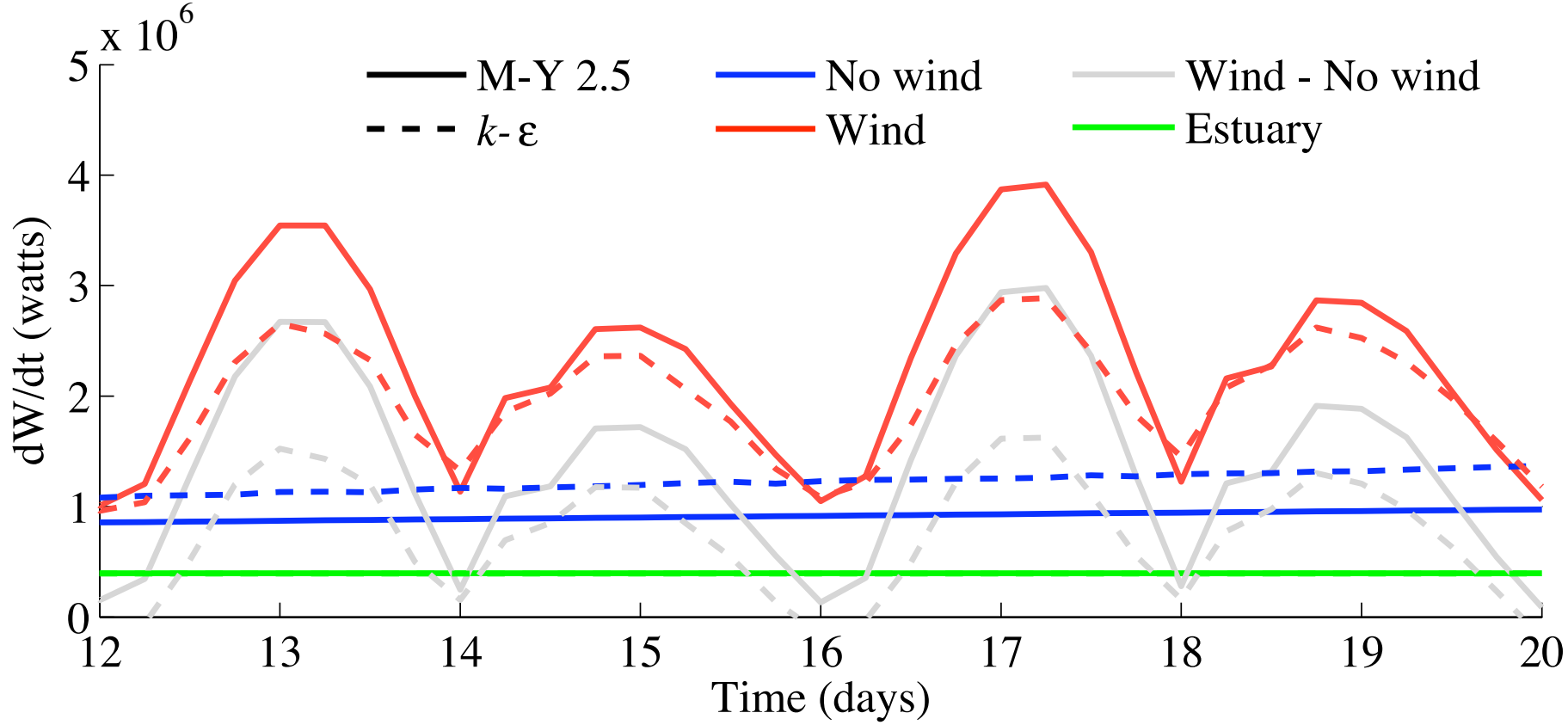


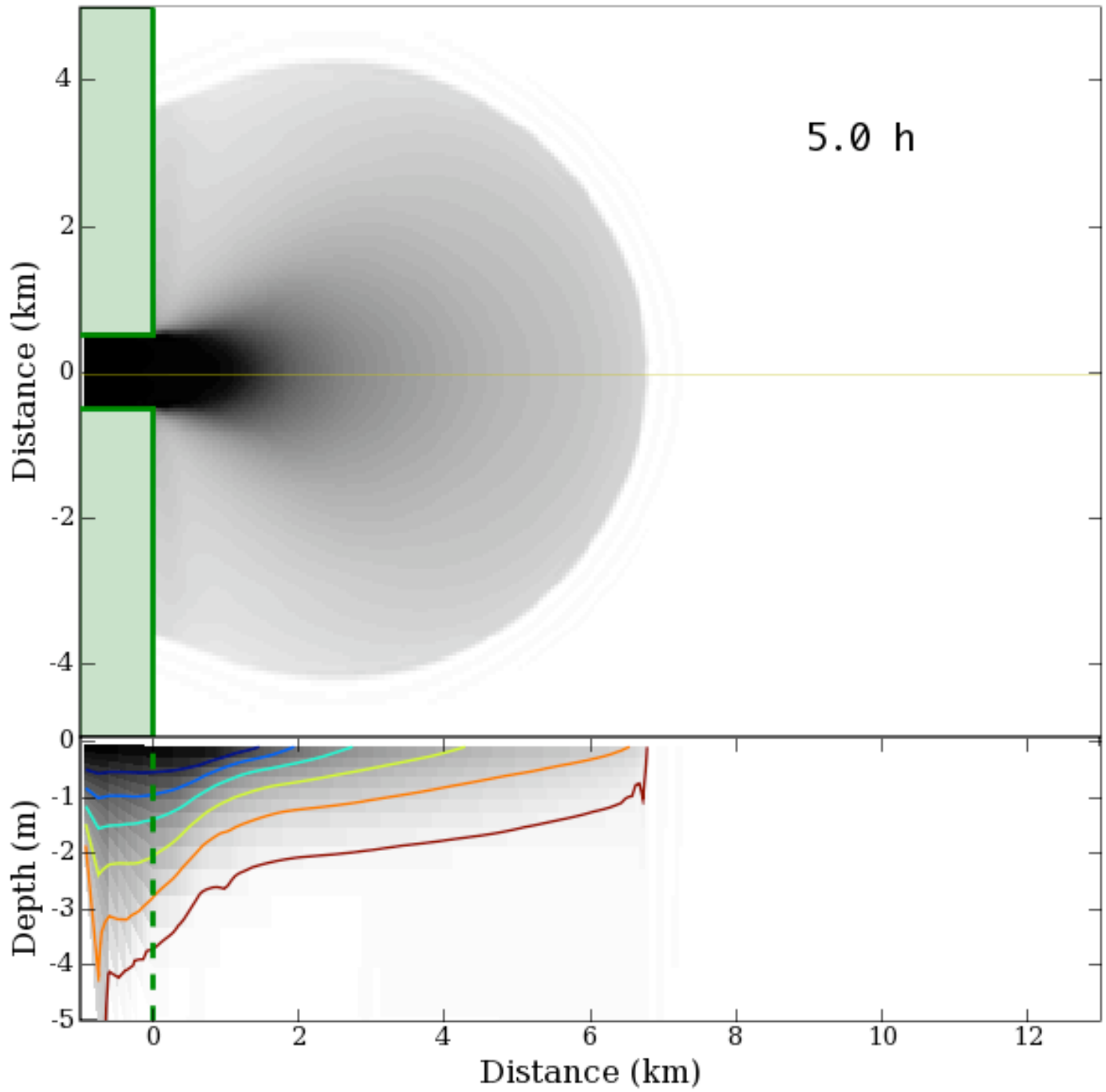

Advective region
(near-field)
Wind dominated region
(far-field)
River
Estuary
Plume
Ocean
Shear mixing
(Upstream
wind mixing)
Wind mixing


10
0
-10
-20
-30
-40
-50
-60
Distance (km)
0
10
20
30
Distance (km)
0.3 m s-1
20
25
30
Sea surface salinity (psu)
-5.5
-5
-4.5
-4
-3.5
κ ∂S/∂z|z=-h
0
0.5
1
1.5
2
Froude number


Upwelling
Downwelling
Along−shore distance (km)
Cross−shore distance (km)
20
0
−20
−40
−60
−80
−100
0
10
20
30
40
50
26
27
28
29
30
31
−3.5
−4
−4.5
−5
−5.5
κ s_z|z=−h

Work done by mixing




5.0 h
Distance (km)
4
2
0
-2
-4
Depth (m)
0
-1
-2
-3
-4
-5
0
2
4
6
8
10
12
Distance (km)

Near-field plume Layer model

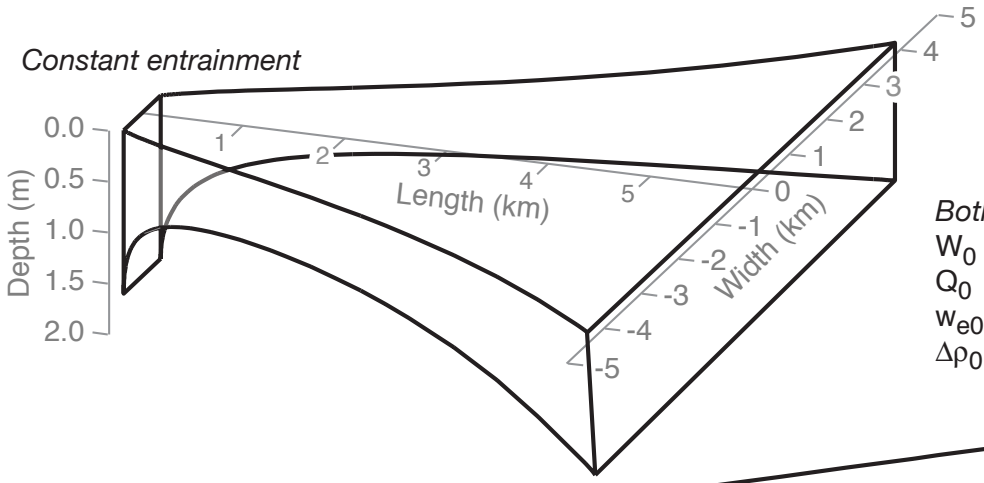
$$\frac{\partial \Delta\rho}{\partial x} = -\Delta\rho \frac{w_e}{u h}$$

$$\frac{\partial W}{\partial x} = 2Fr^{-1}$$

$$\frac{\partial u}{\partial x} = \frac{u}{(1 - Fr^{-2})} \left[\frac{\Delta\rho_x}{\Delta\rho} + Fr^{-2} \frac{W_x}{W} \right]$$

$$\frac{\partial h}{\partial x} = -h \left[\frac{\Delta\rho_x}{\Delta\rho} + \frac{W_x}{W} + \frac{u_x}{u} \right]$$

Layer model solutions



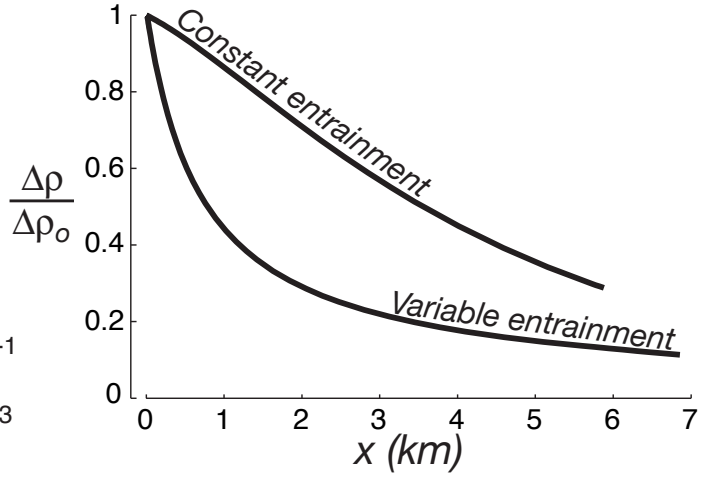
Both cases:

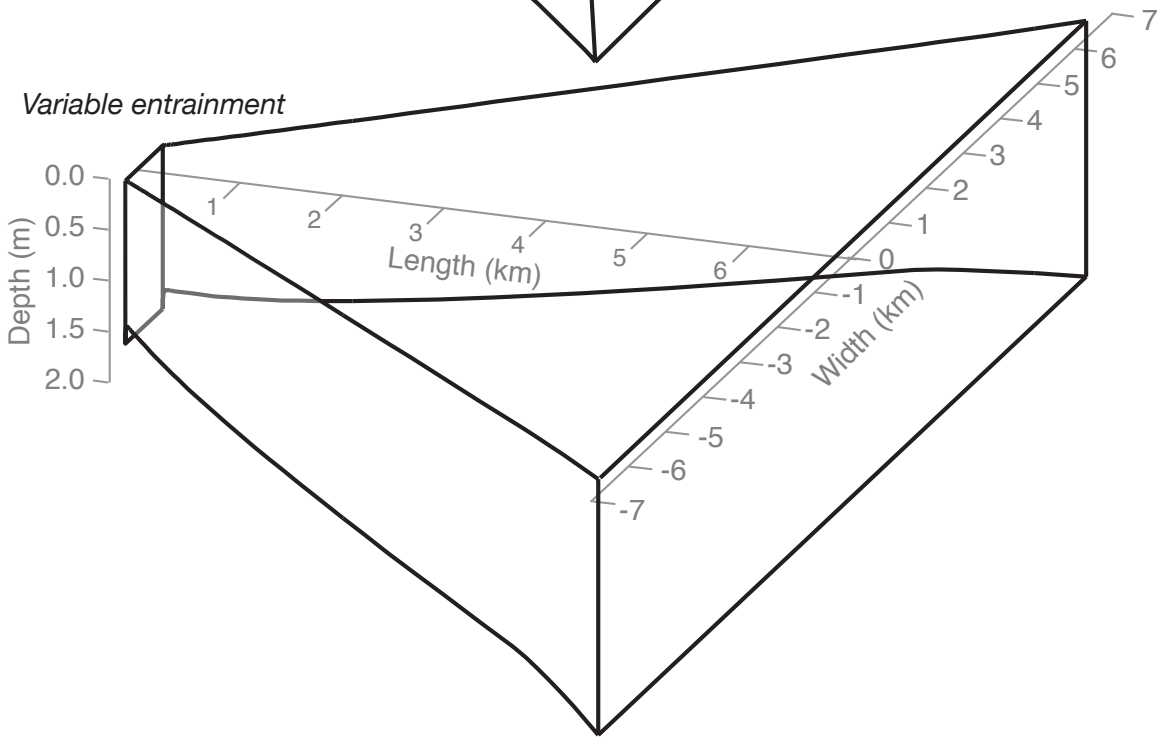
W_0 = 1 km

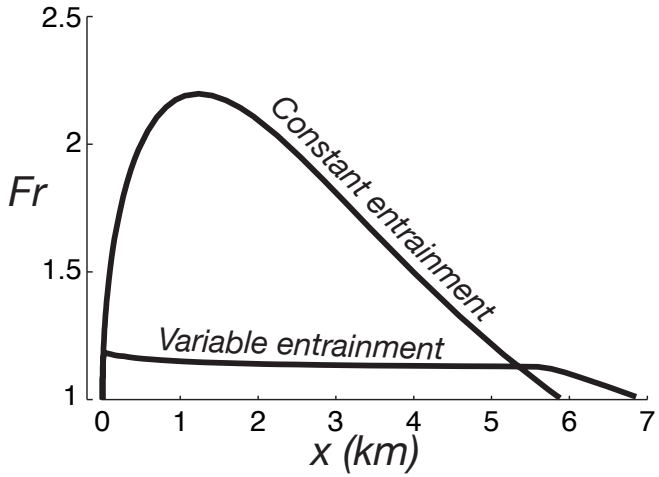
Q_0 = 1000 $m^3\ s^{-1}$

w_{e0} = 10^{-4} $m\ s^{-1}$

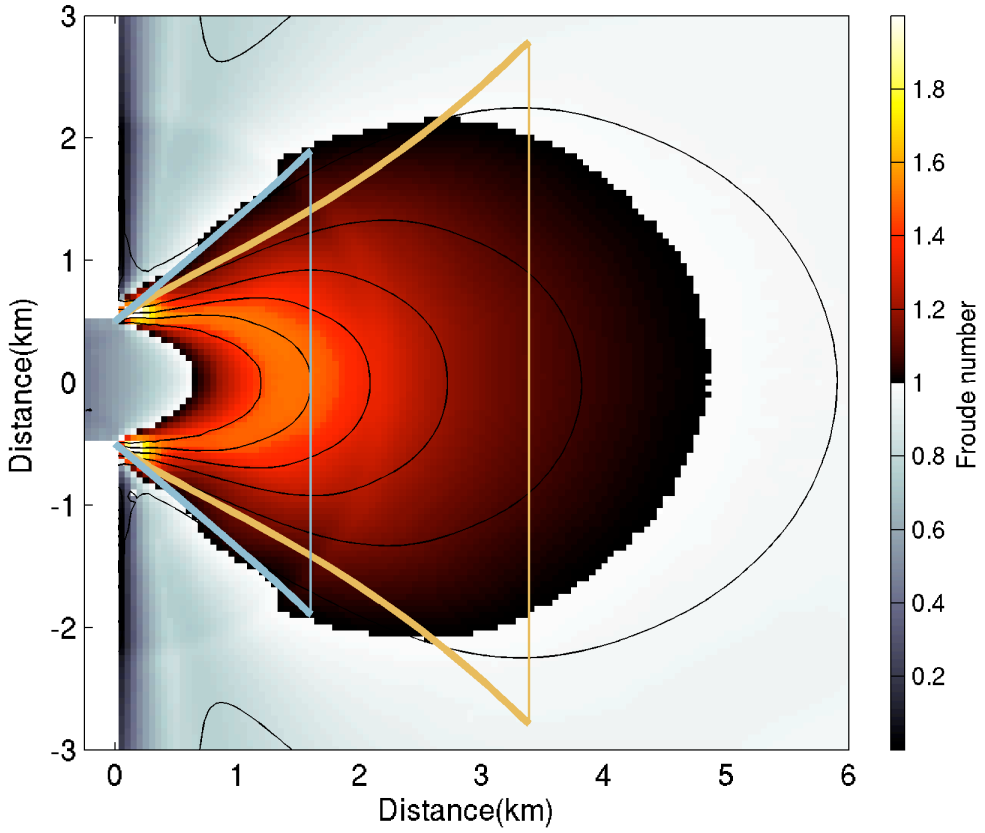
$\Delta\rho_0$ = 24.8 kg m^{-3}

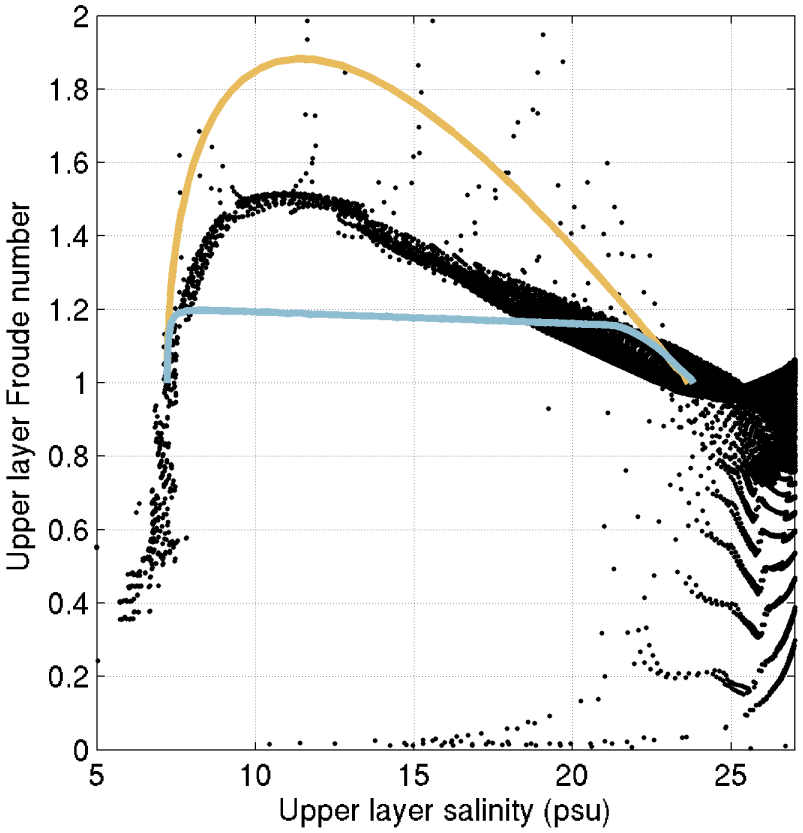






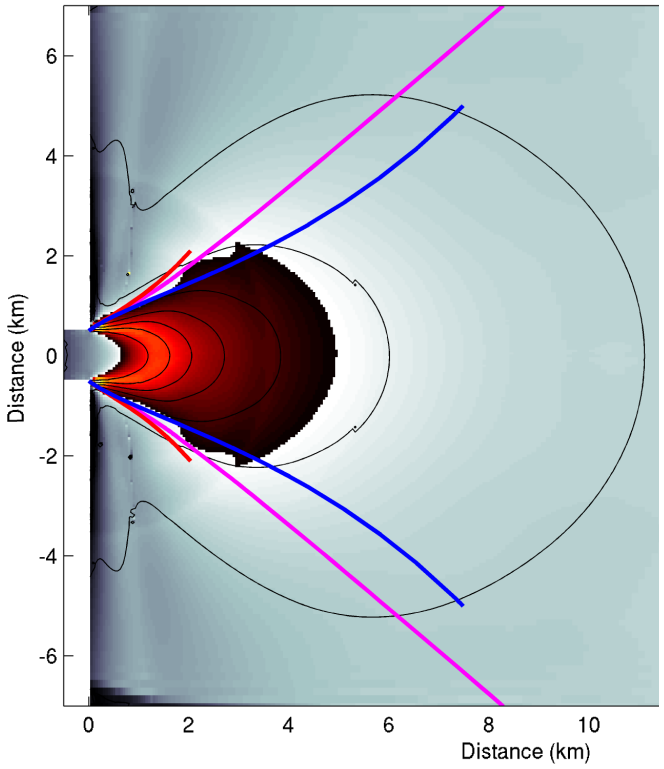
Layer model vs. 3D model



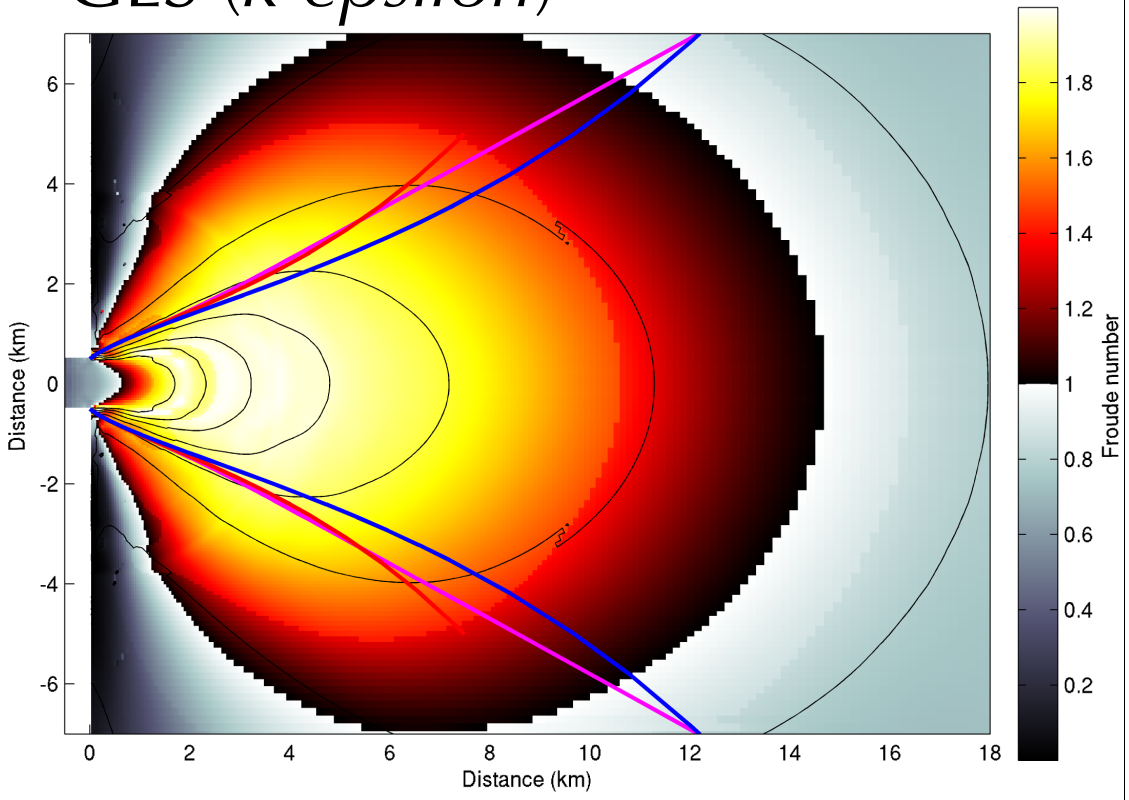


Comparison of mixing schemes

Mellor-Yamada



GLS (*k-epsilon*)



Outflow density (at Fr=1)

$$w_n \equiv w_{e0} W_0^2 Q_0^{-1}$$