Studying Double Diffusive Plumes in a Uniform Ambient with MSCTI

Information Provided by Brace Lee, University of Alberta

“The project is on double diffusive plumes in a uniform ambient, where the plume is initially less dense than the ambient. It is double diffusive in that there are two things diffusing as the plume rises in the ambient. The experiments use a turbulent plume source of hot and saline water rising into fresh, room temperature water.
This is done in a tank, with the plume source released upwards. A pump pushes the fluid into the tank from 2 reservoirs, one salty, one hot.

The MSCTI is used to measure of the temperature and conductivity as it is traversed down the center of the plume. Using a linear approximation that voltage of conductivity Vc is a linear function of temperature T, we measure the slope A and intercept B for 4 different salinities. A and B are taken as linear functions of S.

$Vc = AT + B$

$A = aS + b$

$B = cS + d$

Then through calibration we determine these coefficients and can calculate S given T and Vc.

$S = (Vc - bT - d)/(aT + c)$

For temperatures less than 320 K and salinities less than 15 ppt this is a good approximation.

The density of water is a linear fluction of temperature and salinity. The densitydetermines the buoyancy force acting on the fluid. Initially the plume is positively buoyant due to the excess heat. But as it rapidly cools the fluid becomes negatively buoyant, which counteracts the upwards momentum and collapses the plume.

For each experiment we take several traverses of the plume and calculate the average. This decreases the fluctuation in the measurements due to the turbulence in the plume. A vertical time series image (Figure 1) splices together a series of vertical slices of pixels at the center of the plume during one experiment. The probe is shown traversing down through the dyed plume 9 times at 65 second intervals. This gives a look at how the maximum height fluctuates with time. Ensemble averages for temperature, salinity and density; overlaid upon the individual probe measurements are shown in the ensemble profile figures attached.

There are several applications of this research, but our focus is in the dispersal of hydrogen sulfide through the flaring of sour gas.

This is an important problem for Alberta where 85% of Canada's sour gas is extracted. Studies have shown that in cross winds, common to the foothills of the Rocky Mountains where the greatest amount of sour gas is found, burning efficiency of these flares drops from 98% to as low as 10%. Because hydrogen sulfide is denser than air we have this double diffusive plume of heat and H2S rising turbulently into the environment with a risk of descending and collecting at the surface in lethal concentrations.

We have done a series of experiments and are comparing this data to a theory we are developing that accounts for double diffusion in existing plume theory."

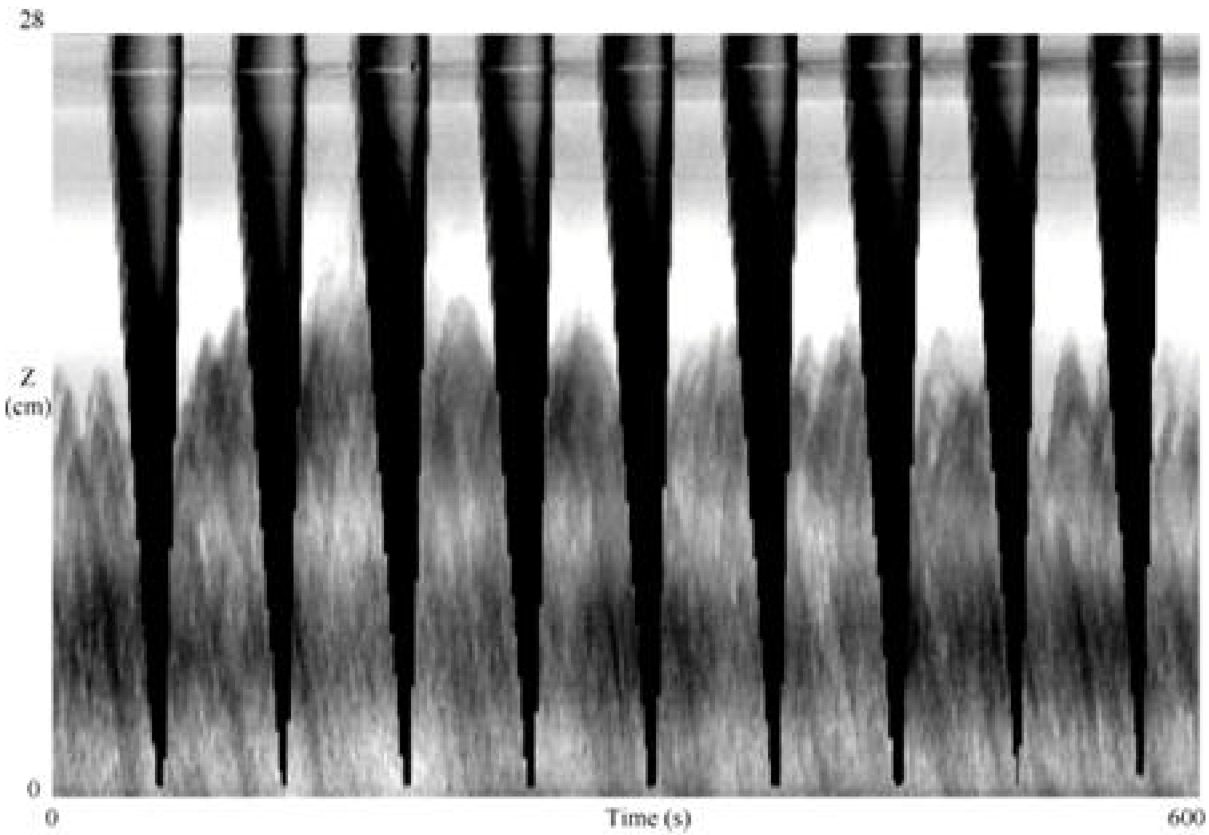

Figure 1, Vertical Time Series