Evaluation and Characterization of Fluid Dynamics in an Annular Flume

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Abstract

The overarching goal of this effort was to design a flow generation and flow straightening system in an annular flume to investigate whether this tank is a suitable testing facility to study sediment transport. The necessary flow field was generated by two 40 [lb.] thrust motors at incremental settings producing flow velocities from 15 [cm/s] to 35 [cm/s]. Flow straighteners then reduced turbulence and straightened the flow downstream for data collection. Three-dimensional velocity measurements were collected at various designated locations downstream using a 3D velocimeter. These readings were used to determine whether the flume was producing the necessary flow field needed to study sediment transport.

An analytic momentum balance was performed to size the flow generators for a range of desired flow conditions. The formulation included both friction due to wall and flow straighteners. This analytic model yielded a necessary maximum power output of 1/8 [HP] which correlates to an output thrust of 45 [lbf] for a flow velocity of 55 [cm/s]. Numerical simulations of the flow field were conducted to evaluate the flow straightener performance and predict the optimum sampling location. These simulations indicated a 1.5 [in] diameter tube in a honeycomb array was the model that resulted in the least amount of frictional loss. Also it was found that at a 15° arc radius the flow straighteners performed the best at straightening the downstream flow.

Next, the flow generation and straightening system was constructed. 2 Minn Kota 40 [lb.] thrust motors were purchased from www.cabelas.com. These motors were mounted to the flume using supplies from the Chase Ocean Engineering building. Flow straighteners were constructed in a honeycomb style using rendered measurements taken from the analytic model. This tube array was then placed 45 degrees from the outboard motors. Proper measurements were taken into consideration if the flow straighteners had to be moved up or down stream.

Finally, the velocity field within flume was measured to evaluate the flume performance and hydrodynamic sampling regime. A mounting system was constructed using supplies from the Chase Ocean Engineering building. An angle iron was bolted to the mounting system and fitted with 2 parallel horizontal slots to allow for translation from inner flume wall to outer flume wall. A Vectrino II velocimeter was the instrument used to record the flow velocity. Both x and y flow velocities were recorded along with 2 estimates in the z direction. Using these recordings the data was then exported to Matlab for further investigation. Upon analysis it was determined that an annular flume is an acceptable facility to study sediment transport. An optimal testing location was found to be 12 [ft] from the flow straighteners along the outer flume wall.

1 Introduction

The overarching goal of the project is to validate a testing facility to study sediment transport. The facility under investigation is a circular open channel flume. An annular flume has not been used before in studying sediment transport due to the experimental requirements to study this theory.

The study of sediment transport is the study of the recirculation of solid particles. A correlation to sediment transport is understanding erosion in steady flow open environments. As a result, the experimental requirements to study sediment transport are that the flow has to be steady with a flow range of 0.0 [m/s] to 0.4 [m/s].

This tank will be under investigation to see if the flow meets these requirements. In order to meet these requirements, the implementation of a driving force to move the fluid as well as a flow straightener design will be integral. The motors will force the fluid along the tank in order to create the flow speed necessary. With the flow field up to speed, given the tank geometry, the turbulence will be reduced with the flow straighteners. These two integral pieces will create a suitable testing section downstream.

2 Analytic Model

Upon our initial approach to validating this testing facility, the flow needs to be forced through the tank. An analytic model of the flume was created to understand the amount of force needed to drive the flow at our desired flow speed.

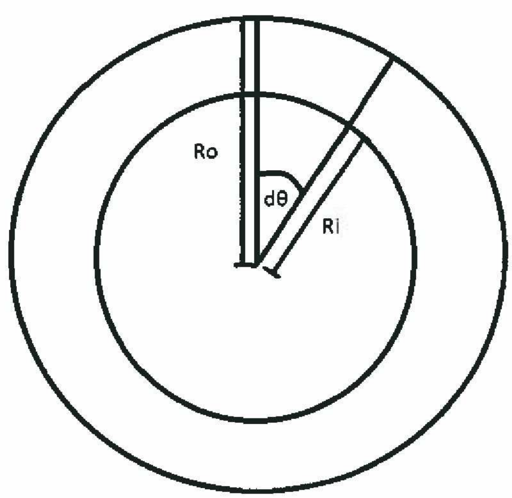

Figure 2-1: General tank geometry.

The force driving the flow results from an outboard motor that must overcome initial frictional losses. The frictional forces that will need to be overcome include the friction due to the inner and outer walls as well as the bottom floor of the tank. The outboard motor will result in significant rotational motion that will generate large vortices that will require flow straighteners. The flow straighteners should reduce the overall downstream turbulence but will be an additional sort of friction the must be considered. The two flow straightener designs under consideration are a honeycomb style curved tube array and a porous block design.

A volumetric momentum balance was used to determine the necessary motor power to generate the specified flow for measurements downstream. The volumetric form of the momentum balance (Kundu 2012:101) accounting for frictional losses on the walls, flow straighteners and thrust by the propeller, can be rewritten as

$$F_{thrust} + F_{friction} + F_{flow\ straightener\ friction} = \frac{d}{dt}\int_{V} \rho u \, d\forall + \int_{A} \rho u (u \cdot n)\, dA \quad (1)$$

where ρ is the density of the fluid, u is the velocity field, n is the direction of the flow relative to the control volume, and F is the external force acting on the fluid. Continuity is in 2-D cylindrical coordinates due to the flume geometry. For 2-D cylindrical coordinates, the velocity field is represented with $u(r,\theta)=U_r\, i_r+U_\theta i_\theta$. The continuity equation is

$$\frac{\partial \rho}{\partial t} + \frac{1}{r}\frac{\partial}{\partial r}(r\rho U_r) + \frac{1}{r}\frac{\partial}{\partial \theta}(\rho U_\theta) = 0 \quad (2)$$

where the assumption of U_θ. Please note, this analysis neglects the vertical velocity contribution. With a resulting constant velocity placed back into the momentum equation, the resulting reduced form can be written as

$$F = \frac{\rho C_f U_\theta^2 A_{surf}}{2} \quad (3)$$

where ρ is the fluid density, U_θ is the mean velocity along the curve of the tank of the fluid, C_f is the coefficient of friction for water in an open channel, and A_{surf} is the surface area of the walls and flow straighteners. The coefficient of friction for water in an open channel can be approximated with

$$C_f = \frac{0.075}{(log10(Re)-2)^2} \quad (4)$$

where the coefficient of friction is a function of the Reynolds number and defined as a dimensionless number that measures the ratio or inertial forces to viscous forces which determines the type of flow the fluid is. The Reynolds number is calculated by

$$Re = \frac{UL}{\nu} \quad (5)$$

Where Re is the Reynolds number, U is the characteristic velocity of the fluid, L is the characteristic length scale defined by the hydraulic radius, and ν is the kinematic viscosity. The dimensions of the tank result in a cross sectional area of 2 [ft] and ¾ [in] resulting in a hydraulic radius of 5.95 [in]. By having both the cross sectional area and perimeter of the fluid against the tank, the hydraulic radius, L, is the characteristic dimension in an open channel flume and is defined with

$$L = \frac{A_{cross}}{P} \tag{6}$$

Where A_{cross} is the cross sectional area of the tank, divided by the wetted perimeter.

The wetted perimeter is determined with

$$P = 2H + B \tag{7}$$

Where P is the perimeter, H is the calculated height of the fluid in the tank, and B is the width of the base of the tank. The water height was measured by the equation below

$$H = \frac{A_{cross}}{B} \tag{8}$$

Through the Reynolds number, the flow field is characterized to be turbulent. The following figure shows the Reynolds number increasing as the velocity increases.

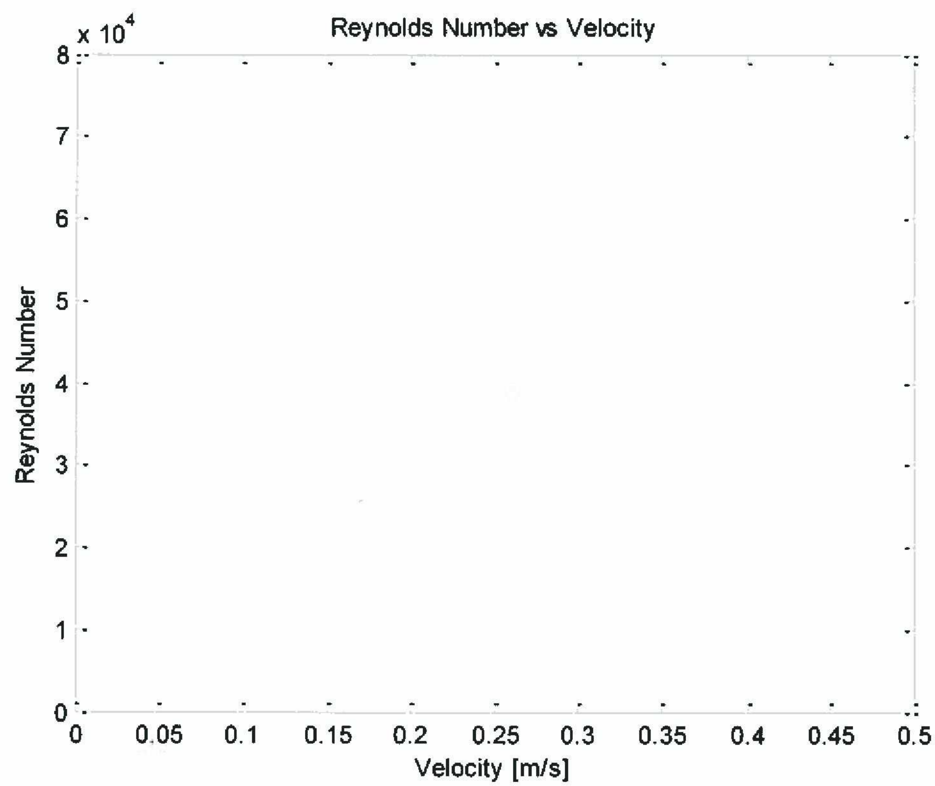

Figure 2-2: Reynolds number over a velocity range of 0.0 to 0.5 [m/s.]

When accounting for the frictional losses, the surface area of the tank included the tank bottom and side walls, as well as, the surface area of the flow straightener tubes that the fluid passed through. In order to evaluate the independent frictional contributions, the surface area is the sum of the individual components

$$A_{surf} = \sum A \tag{9}$$

Calculating for the tank walls, the surface area of the bottom of the tank is

$$A_{bottom} = \pi\left(\left(\frac{OD^2}{2}\right) - \left(\frac{ID^2}{2}\right)\right) \tag{10}$$

Where OD is the outer diameter of the tank, and ID is the inner diameter of the tank. Also, the friction due to the walls can be calculated by

$$A_{wall} = 2\pi(ID + OD)H \tag{11}$$

Where A_{wall} is the surface area of the walls, H is the water height, and both OD and ID identify whether it is the surface area of the outer wall or inner wall. In the case of the tube array flow straighteners, the flow moves along both the inside and ouside surface of the tubes and the surface area is

$$A_{Flow\ Straightener\ array} = n * (\pi oDrd\theta + \pi iDrd\theta) \tag{12}$$

where the surface area along the length of the flow straightener tubes is a function of n, the number of tubes, oD and iD which are the outer and inner diameter dimensions of the tubes, r being the average radius from the center of the tank, and dθ being the curved length in radians. R.I.Loehrke and H.M.Nagib (1972), showed experimentally that the ratio of the length of the tubes and the centerline width of the tank should be on the order of one. Also, the diameter of the tubes should be approximately $1/10^{th}$ the tube length. With these design specifications, only the friction along the tube walls is included due to the face of the tubes being small enough to be considered negligible.

A porous block with an array of straighteners integrated in the block creates surface friction from the blocked crevices between each straightener tube. This surface friction along with the flow through the tubes creates a more viscous flow, changing the analysis process as well as making the flow more turbulent than before. With the flow only passing through the holes in the block, the surface area along the holes is

$$A_{Flow\ Straightener\ Block} = n * (\pi IDrd\theta) \tag{13}$$

Where there is only friction due to the inner walls of the holes. Also due to continuity, the flow increases consequently from the Reynolds number, through the block.

The theoretical power required to overcome the frictional forces is

$$Power = FU \tag{14}$$

where the force over the velocity represents the power of the trolling motors in Watts. This relationship is used to assess the power demand to overcome the frictional forces so the flow field is held constant. The expanded power equation becomes

$$Power = \frac{\rho U^3 c_f}{2}[A_{bottom} + A_{walls} + A_{Flow\ Straighteners}] \tag{15}$$

Where the expanded form of the friction force is multiplied by the velocity including all frictional components. In order to use this power value and compare it to motor sizes for the use of the thrust, power is converted from Watts to horsepower through

$$HP = \frac{Watts}{745.7[\frac{Watts}{HP}]} \tag{16}$$

Where the final value in Watts is divided by a constant to convert into HP to determine the necessary size of the motor.

Upon configuring the power necessary to drive the flow, the two flow straightener designs were compared for an optimal design in the following figures. The first figure displays the power needed to compensate for the porous block design

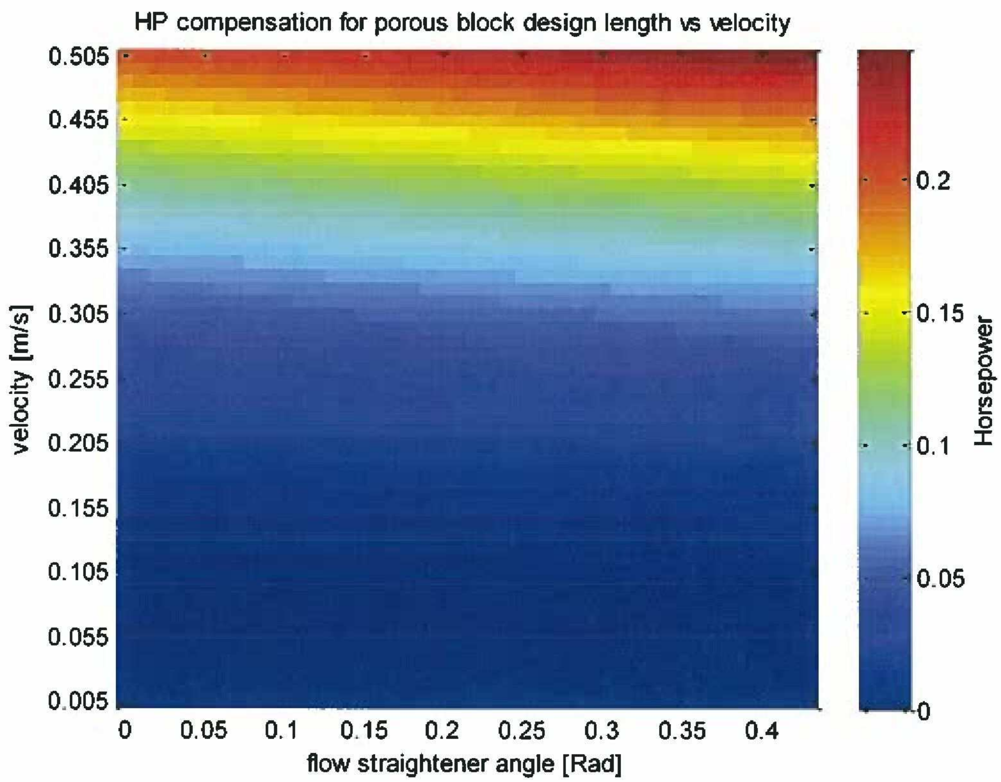

Figure 2-3: Power consumption for porous block flow straightener design.

Figure 2-2 shows that the maximum amount of power necessary to compensate for the porous block for flow straightener angles of 0 to 0.4 radians ranges from 0.2 to 0.25 [HP]. Also, a larger difference is show through the flow field; this is a result of the Reynolds number increasing greatly as the velocity increases. The amount of power from the porous block design doubles the amount of power needed to compensate for the honeycomb tube array design. The following figure shows the power compensation for the tube array design

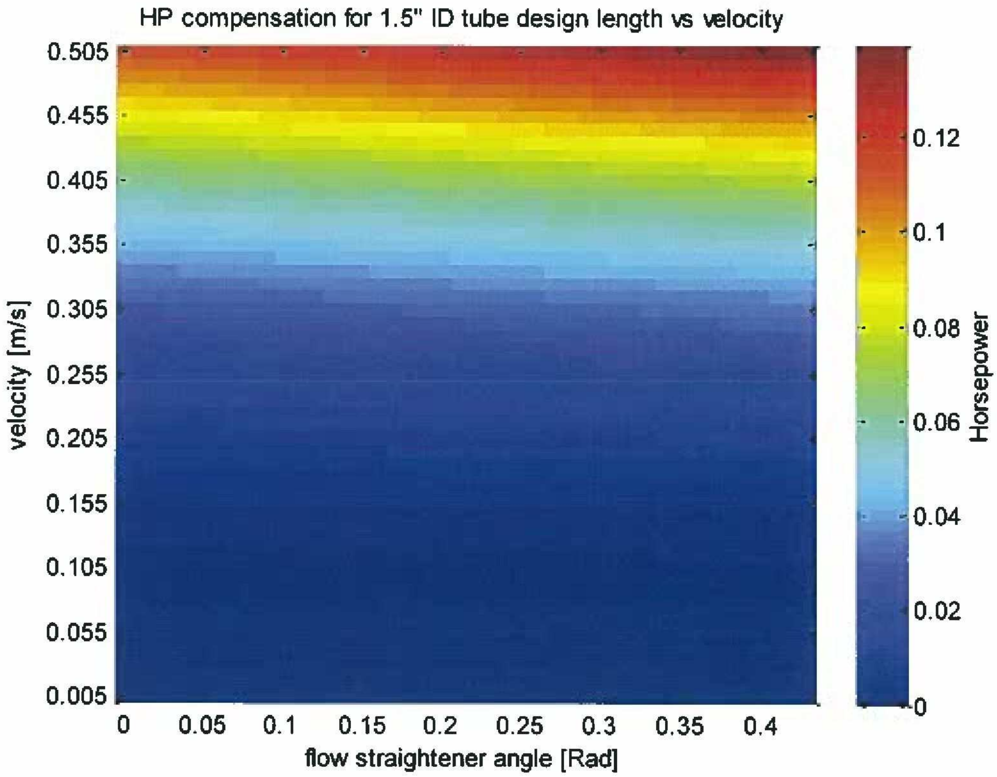

Figure 2-4: Power consumption for honeycomb array flow straightener design.

This figure displays a reduced amount of power, with a maximum value of approximately 1/8 [HP]. The two designs are different in values, but show symmetry in their sensitivity to the length of the flow straighteners.

For a tube array design being the optimal flow straightener design, there are some calculations in order to find out how much tubing there is involved. Through researching R.I.Loehrke and H.M.Nagib (1972), the optimal arc angle, dθ, is a 15 degree arc. With the dimensions of the tank and the flow straightener tubes known, the length of an individual tube is given by

$$L_{arc} = \frac{d\theta}{360} 2\pi R \tag{17}$$

Where the arc length is a function of the arc radius. With the arc radius being a range of values, the arc length becomes an array of tubes along the width of the tank. The array of tubes produced is the individual lengths in meters per radial length.

3 Numerical Analysis

Before collecting observational data, two important factors need to be determined in order to collect accurate data, the location of the flow straighteners relative to the motors and the optimal testing section downstream from the flow straighteners. This was addressed with numerical simulations of the flow field using Solidworks Flow Simulation .

The tank was assumed to the a rigid lid system with a known water depth of 12 [in]. The flow was analyzed as an internal flow. Two different simulations were performed. The first simulation examined the theoretical flow without flow straighteners to determine if they are necessary. The second model included our optimal flow straightener design of a honeycomb style tube array.

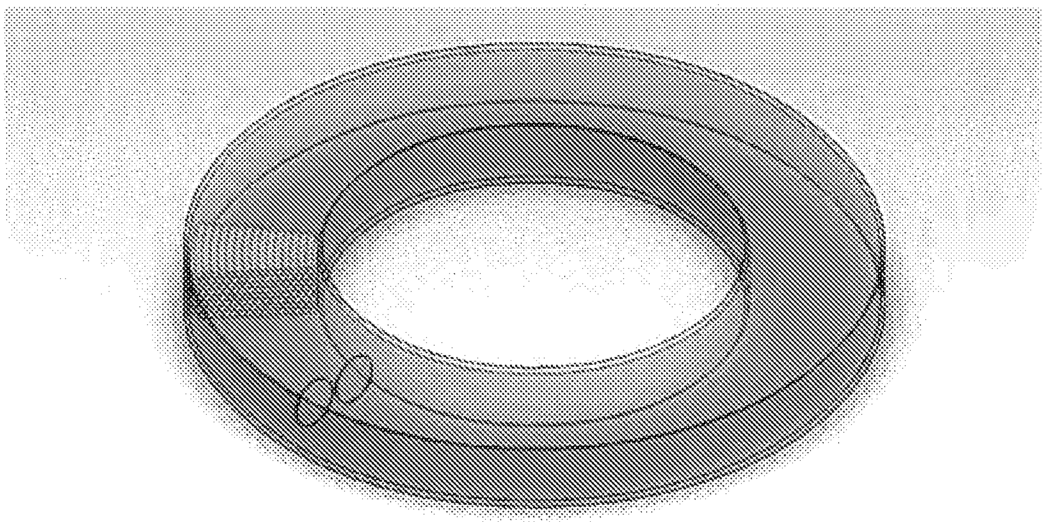

Figure 3-1: Simulated tank model.

The necessary boundary conditions were that all of the tank walls, as well as any real object inside the tank were defined with real wall conditions. In a real wall, the wall boundary layer includes the viscous effects of the walls to approximate the velocity, turbulent kinetic energy and dissipation with a known wall roughness. An overall surface roughness factor was estimated as Ks=0.02 [mm]. Another critical boundary condition is the inlet velocity. To simulate the flow being driven by the motors, two thin discs containing the same diameter of the propeller blades are inserted in the tank. The front face of the disc contained an inlet velocity of 0.75 [m/s] normal to the disc face as well as a spinning velocity of 1.67 [rad/s]. This inlet normal and spinning velocity simulates the initial flow driven from the motors and results in a mean flow downstream flow speed of approximately 0.3 [m/s]. In this simulation, the back faces of the two thin discs were to be the static pressure points.

Figure 3-1 displays the flow field magnitude without the use of flow straighteners.

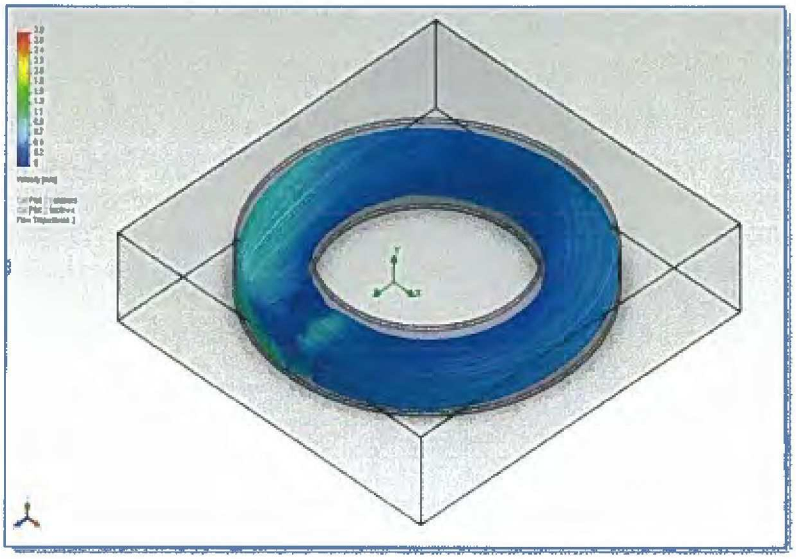

Figure 3-2: Initial simulation without flow straighteners.

The different colored lines represent the average downstream velocity trajectories throughout the tank. As the colors of the lines turn from blue to red, the velocity increases. The figure shows that the disturbance created by the motor is largest immediately downstream of the motors. Without the flow straighteners, the simulation shows that the flow filed approaches an equilibrium state at roughly 180 degrees downstream of the motor.

The figure also shows that the flow is faster at the outer side wall.

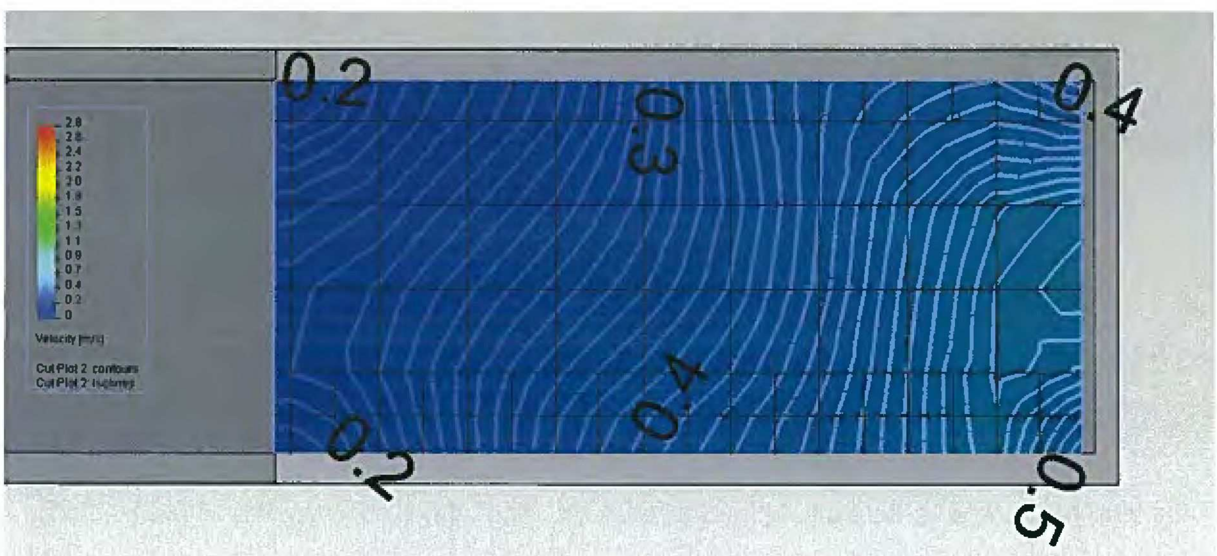

Figure 3-3: Optimal testing location without flow straighteners.

Despite this location being the optimal testing location, the velocity field shows significant across tank velocity with flow speeds ranging from 0.2 to 0.5 [m/s]. the non-uniformity would significantly restrict the use of the tank for sediment transport studies. The flow straighteners were added to the domain at an optimal 45 degrees from the motors downstream. The simulation shows that the flow field is stabilized by approximately 135 degrees. Beyond 135 degrees, the flow field is predicted to be uniform until approximately 300 degrees.

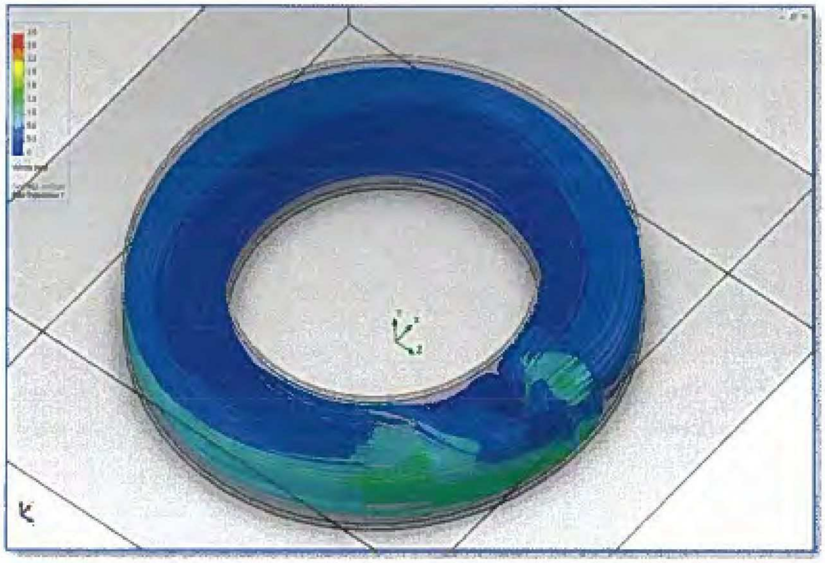

Figure 3-4: Theoretical flow with flow straighteners.

The flow passing through the straighteners shows a local increasing magnitude but begins to spread and dissipate across the whole tank. The flow downstream is steadier as shown by the darker blue color. With the straighteners in this model, the optimal testing location is approximately 180 degrees from the end of the flow straighteners. This cross section is shown below

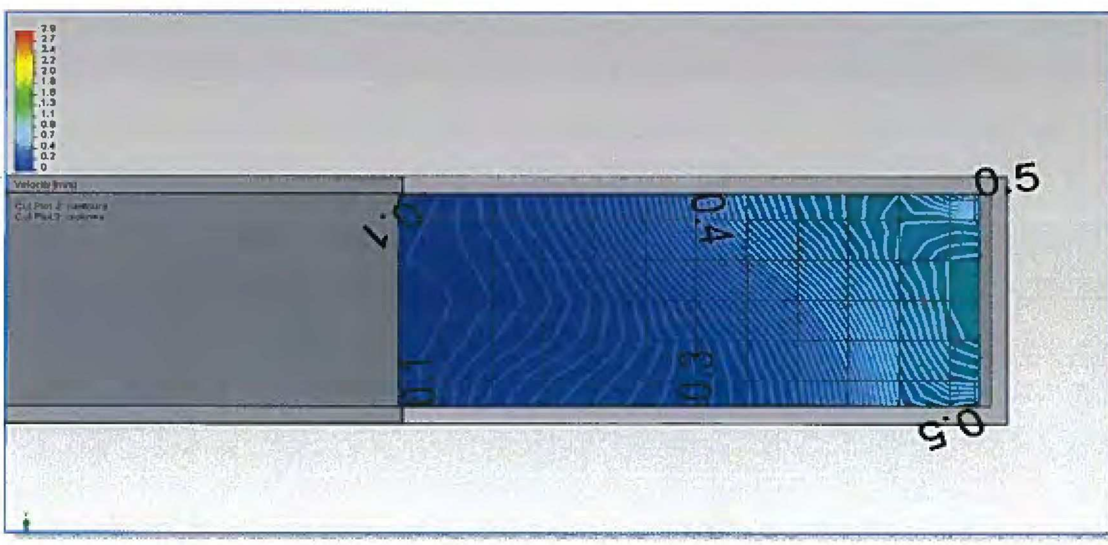

Figure 3-5: Theoretical cross section corresponding to optimal testing location in flume.

The values of the flow shown in the figure display that the flow downstream are steady and increase from inner wall to outer wall like it should. Unfortunately, the model including the flow straighteners shows a larger difference between the flow field from inside wall to outside wall.

As a result of this simulated analysis, the flow straighteners can be placed approximately 45 degrees or more downstream from the motors to reduce the turbulence. Lastly, with the straighteners placed in the tank, the optimal location for testing is approximately 180 degrees downstream from the tailing edge of the tubes. The across the tank uniformity will decrease with the implementation of the flow straighteners, but the along the tank uniformity of the flow field will increase significantly making the flow more steady.

4 Experimental Design

In order to drive the flow in the flume and to collect valid data, three main components were constructed. The flow field was driven by two 40 [lb]. thrust outboard motors secured at a safe distance from all surrounding walls using wood screws, clamps, and U-bolts. Motor shafts were securely fastened to ensure tank liner safety and to prevent torque resulting from motor thrust.

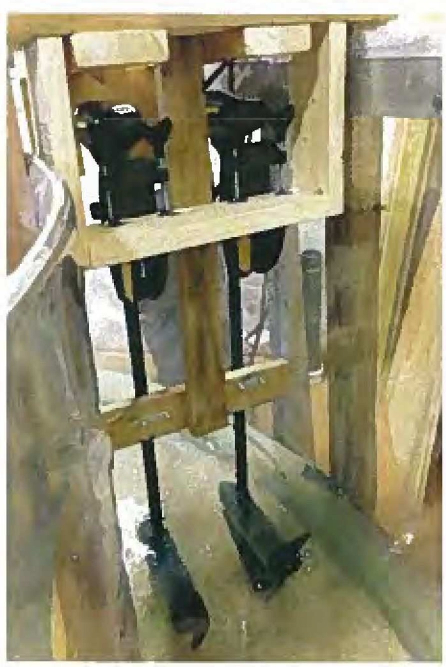

Figure 4-1: Dual 40 lb. thrust motors with mounting system.

The flow straighteners were constructed in a honeycomb style array as given in sections 2 and 3. The material used to make the straighteners consisted of Crack-Resistant Polyethylene Tubing, PVC Glue, and duct tape. The straighteners were constructed and placed in the tank to fit snug against the inner and outer walls. A requirement of the straightener design was to assume they could be placed anywhere in flume to facilitate flexibility in future experiments. Figure 4-2 shows the final model of the flow straighteners.

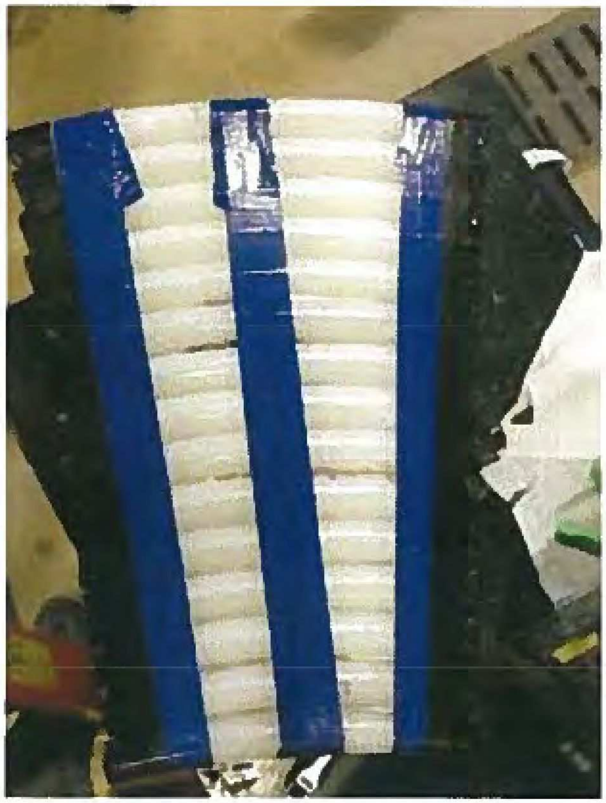

Figure 4-2: Flow straighteners.

In order to obtain accurate velocity measurements, a mount had to be constructed to secure Vectrino II measuring device at a steady location in the flume. The Vectrino II mount followed the same design as the outboard motor mount. Wood screws and clamps were used to make the mount so that it was secured tightly to the flume. Angle iron was fitted with two parallel horizontal slots to allow translation from outer to inner walls for thorough cross sectional measurements. Bolts were used to secure the Vectrino II to the angle iron. The head of the Vectrino II was the only part of the device not secured to the angle iron. If too much of the angle iron was in the water too close to the measuring head there was concern that the flow field would be disrupted and data would not represent the true dynamics.

It was determined that the ideal flow velocity would not cause any movement in the Vectrino head, in turn not resulting in any data collection error.

Figure 4-3: Vectrino II current profiler with mounting system.

5 Observations

Once the motors, flow straighteners, and Vectrino II were implemented in the annular flume testing was conducted. The motors were turned on and let run for 5 minutes to ensure that the flow field was fully developed. Testing consisted of recording flow field velocities using the Vectrino II and analyzing the data with proper scripts in Matlab. The x-coordinate of the Vectrino II head was oriented along the tank with the direction of the flow. A 3 cm depth water column starting 4 [cm] away from the Vectrino II head and ranging to 7 [cm] from the head was the designated data collection volume which can be seen in Figure 5-2.

An initial ten minute run was recorded to investigate the necessary record length required to determine if the flow field was steady with no low frequency or vortex shedding over a long period of time. If periodic vortices shed from the outboard motor or from the flow straighteners it would affect data interpretation. Figure 5-1 shows the energy density of the velocity as a function of frequency for the initial 10 minute run.

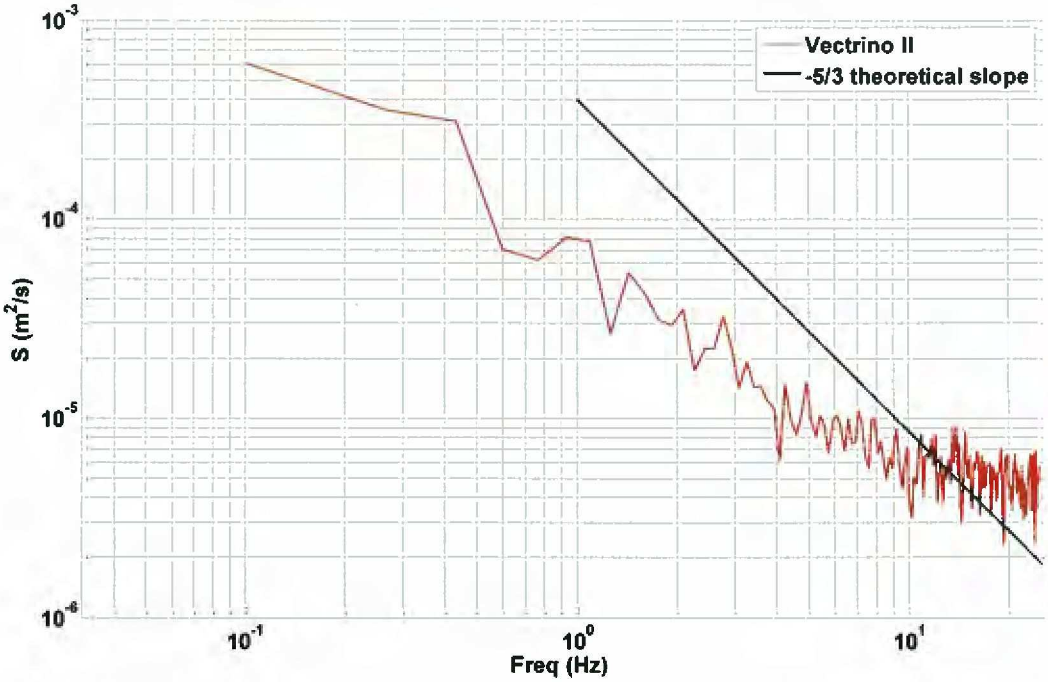

Figure 5-4: Spectral energy plot of 10 minute test.

The power spectral density along the flow direction velocity was calculated using Matlab scripts written by Diane Foster and graduate student Meagan Wengrove. Given that there were no spectrum spikes above the 95% confidence interval a steady flow assumption was valid. This 95% confidence interval was attained by the use of 40 degrees of freedom using the spectrum data plot. In other words, the time series was split up into 2 minute intervals and the data was averaged together resulting in the plot seen below. A two minute run was assumed to be an acceptable sampling time. Figure 5-2 below shows that a 2 minute run follows the same trend as a 10 minute run. To test vertical uniformity, the sensor was raised 4 [cm] and a 2 minute run was then conducted at the new sensor height. It was found that there was minimal variation in the velocity readings and could be considered negligible.

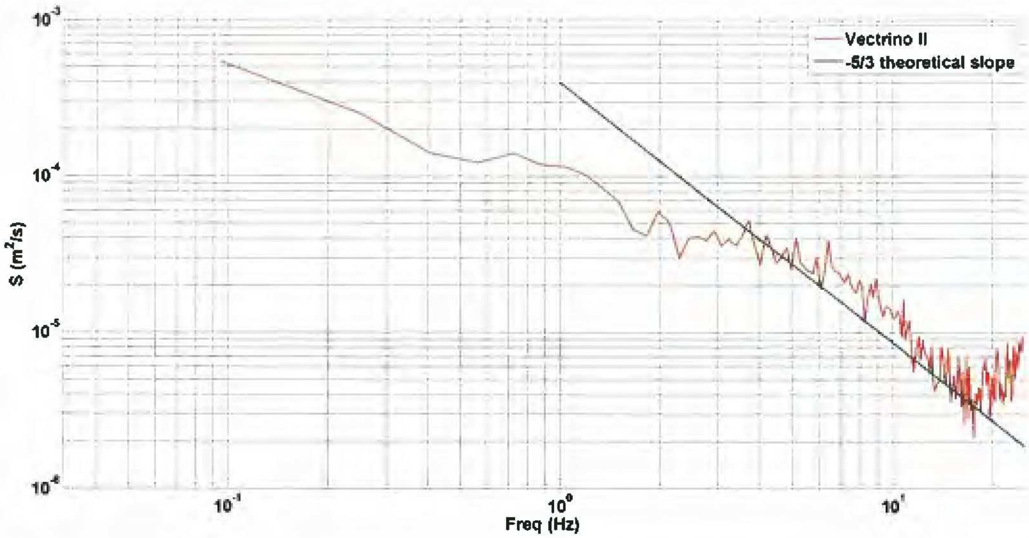

Figure 5-2: Spectral energy plot of a 2 minute test.

This was verified by comparing the spectrum plot of the 2 minute run to the spectrum plot of the 10 minute run and it was observed that they followed the same trend.

This observation indicates that the gathered data follows a typical energy dissipation model where the energy is cascaded from large to small scale. The Vectrino II was sampled at 50 [Hz], which resulted in a Nyquist frequency of 25 [Hz]. Although the sampling frequency has a maximum of 50 [Hz] it can be seen in Figure 5-1 that any data collected above 11 Hz is too noisy to consider. At frequencies greater than 11 [Hz] the spectral energy levels off, suggesting that the instrument noise floor has been reached.

Testing was then conducted at three cross sectional areas along the flume curve. Each test section was 3.33 [ft] along the arc of the tank from the location of the flow straighteners. The data gathered at each test site was then analyzed using Matlab to find average flow characteristics. Velocity readings, correlation factors, and signal to noise ratios were studied to resolve the overall question of whether or not a circular flume is an acceptable test site for the study of sediment transport. Figure 5-3 shows velocity readings in the x and y direction with two estimates in the z direction. The two estimates of the z velocity account for verification of a negligible turbulence in the z direction. It can be seen in Figure 5-3 that the vertical estimates are consistently below 0.00 [cm/s].

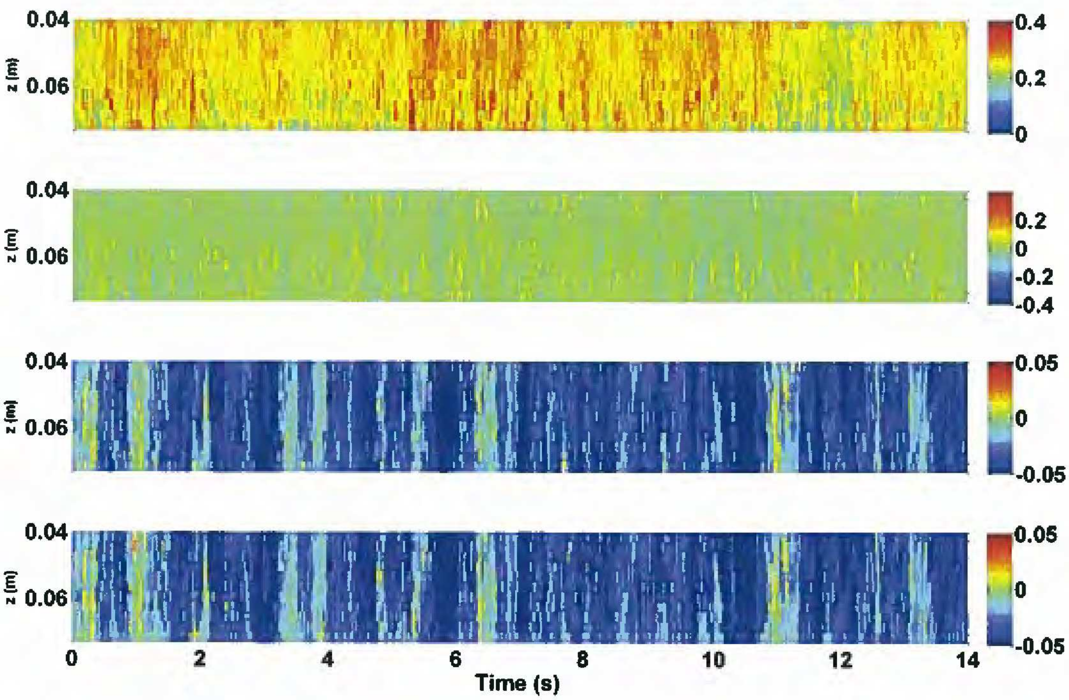

Figure 5-3: Vectrino II 3D velocity readings.

For all data collections the Vectrino II head was located 13 [cm] from the bottom floor. At each test section velocity readings were collected at 3 different translational positions to investigate the changes in velocity from the inner wall of the flume to the outer wall of the flume. The measurement locations were 5.5 [in] 10.25 [in] and 17.125 [in] from the outer flume wall. We observed that the velocity readings closer to the inner flume wall were between 10-15 [cm/s] slower than the velocity measurements taken at the outer flume wall. This trend can be seen in Figure 5-4 below.

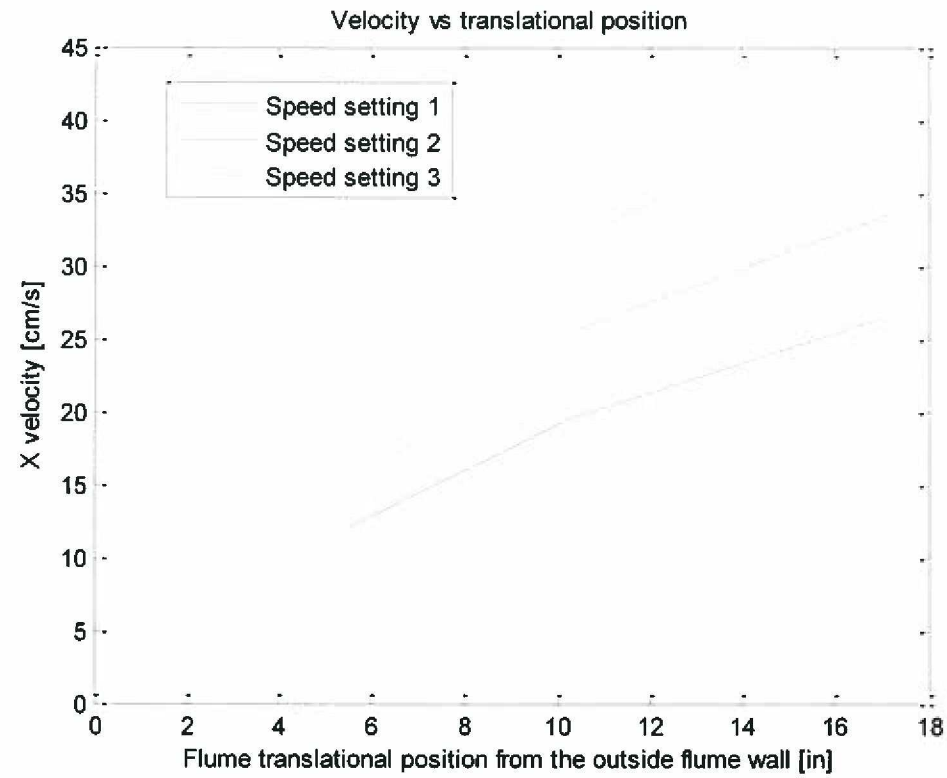

Figure 5-4: X directional velocity vs. translational position from inside flume wall to outside flume wall.

Figure 5-4 shows that for all speeds the velocity significantly increases from the inner to outer flume wall. For example, at speed setting one the test section closest to the outer flume wall recorded an X velocity reading of 26.5 [cm/s]. The test section closest to the inside flume wall recorded an X velocity of 12 [cm/s], which is 14.5 [cm/s] lower than the outside test section. This observation indicates that the flow field is not uniform in the translational direction perpendicular to the flow. This result is not inconsistent with the flow simulation and would suggest that for the flume to applicable for sediment transport studies, the flow generation would be need to be modified. One approach would be to move the motors closer to the inner side wall.

After thorough analysis of collected velocity readings Figure 5-5 below shows the data set collected at the optimal location.

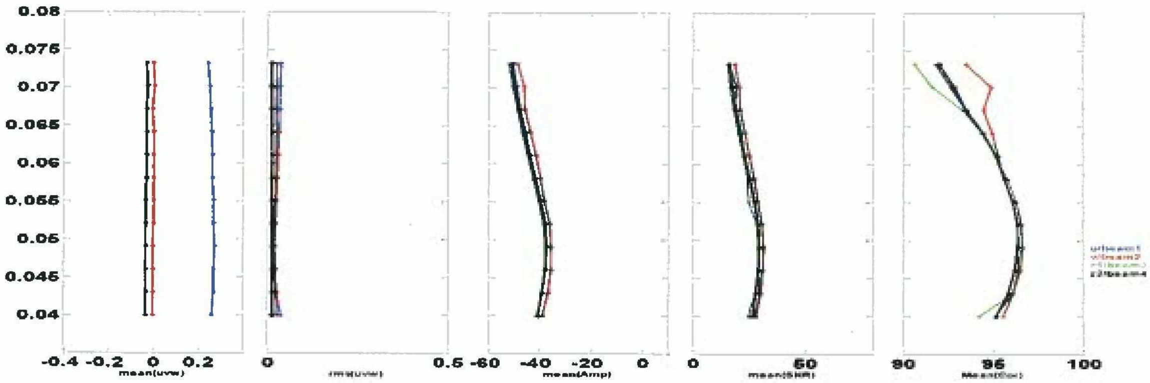

Figure 5-5: Mean velocity, correlation factor, signal to noise ratio.

Figure 5-5 shows an acceptable signal to noise ratio indicating minimal particle scatter in the water column and a correlation factor in the range of 90 to 100%. It can be seen that the x velocity is an acceptable flow speed to study particle movement while the y and z velocities remain at 0 [cm/s] deviating from this measurement by only 1.2 [cm/s]. This small deviation shows that the turbulence at this location is minimal and negligible in the study of one directional particle movement. From our observations, it was confirmed that this annular flume is an acceptable testing facility to study sediment transport. The data collected shows that the optimal testing location for sediment transport in the annular flume is 12 [ft] from the flow straighteners along the curve of the tank. For further analysis at all the test locations, refer to Appendices A and B.

6 Conclusions

Theoretical and experimental analyses were performed to investigate as to whether an annular flume is an acceptable testing facility to study sediment transport. After construction of the necessary mounts and flow straighteners, a Vectrino II velocimeter was used to obtain 3-D velocity measurements at various locations throughout an annular flume. The velocity field within flume was then measured to evaluate the flume performance and hydrodynamic sampling regime. Upon processing the collected data it was confirmed that through modification of the experimental setup an annular flume acts as a suitable testing facility to study sediment transport. If one were to use the annular flume located in Gregg Hall at the University of New Hampshire to study sediment transport, the optimal study location is 12 [ft] from the location of the flow straighteners along the outer flume wall.

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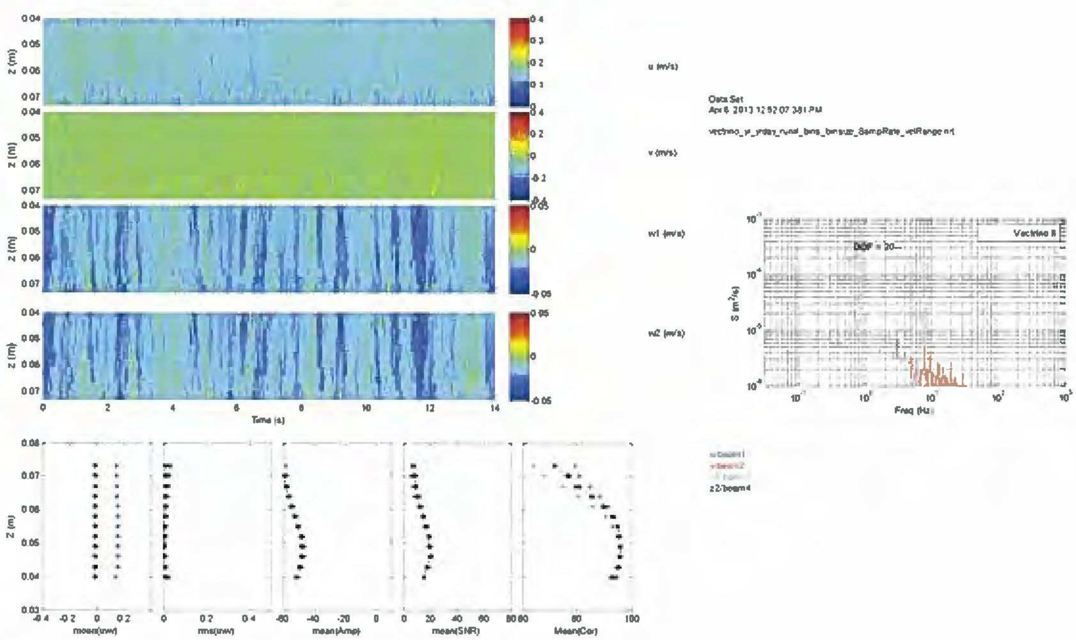
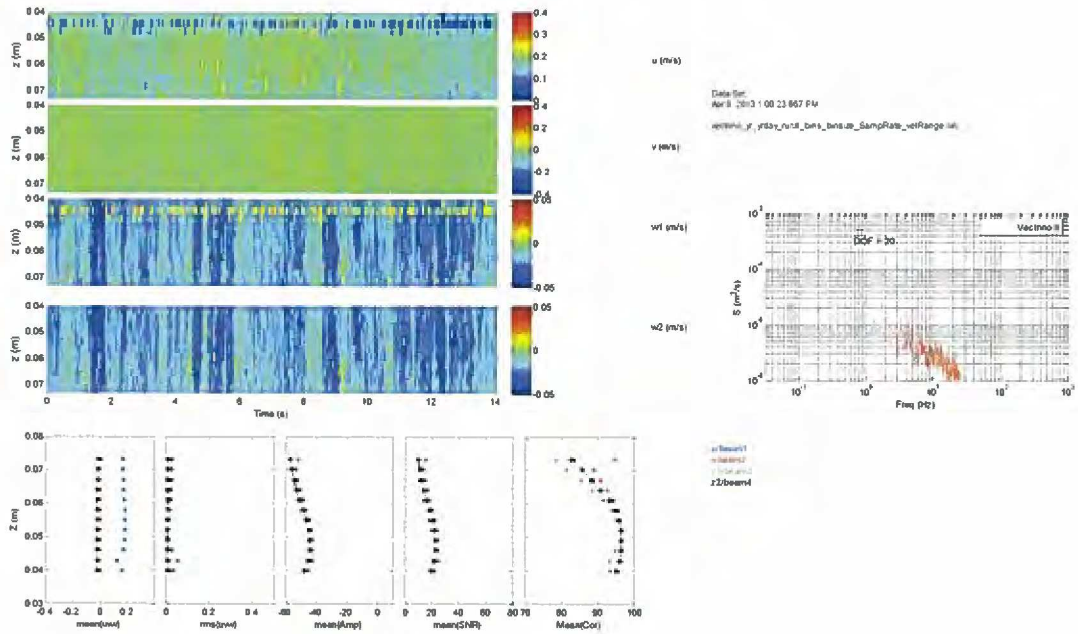
Appendix A

Shown below are the results taken from the research after analysis using the quality control sheets.

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v (m/s)
w1 (m/s)
w2 (m/s)
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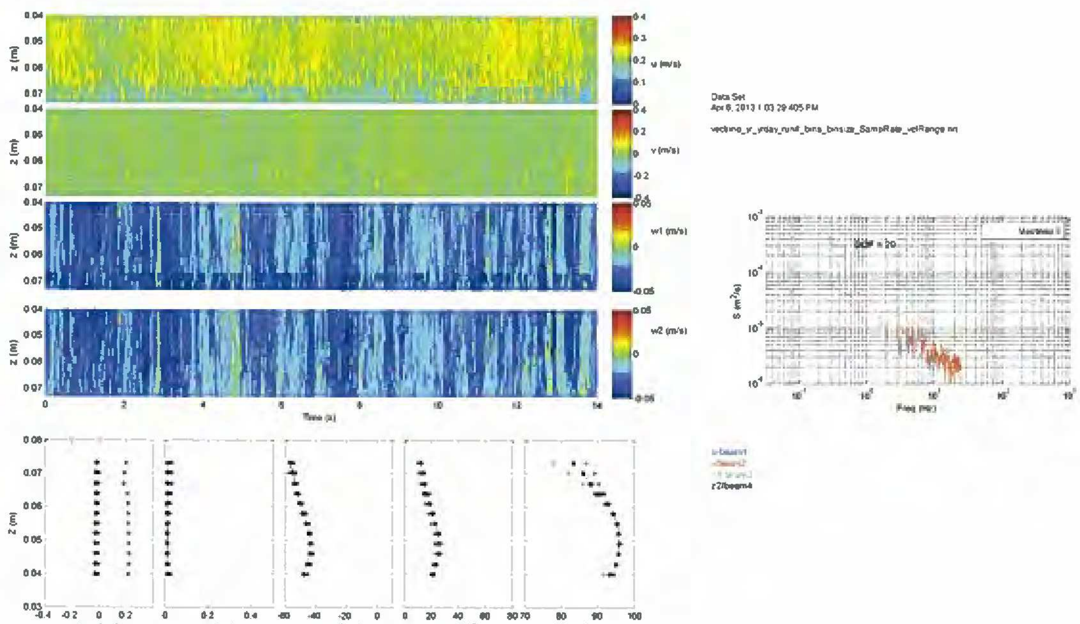
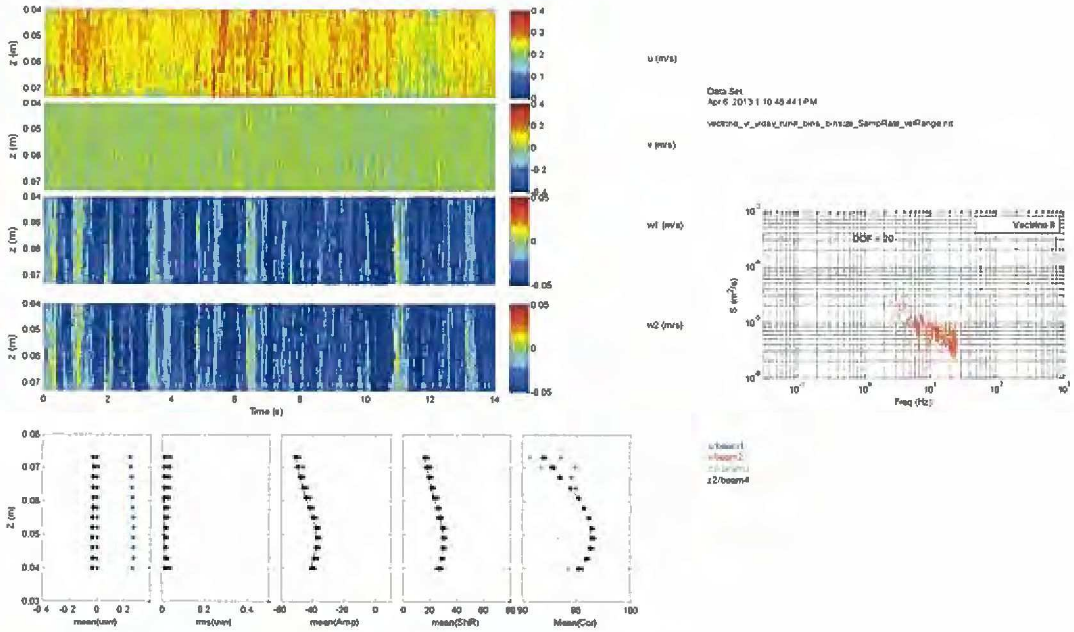
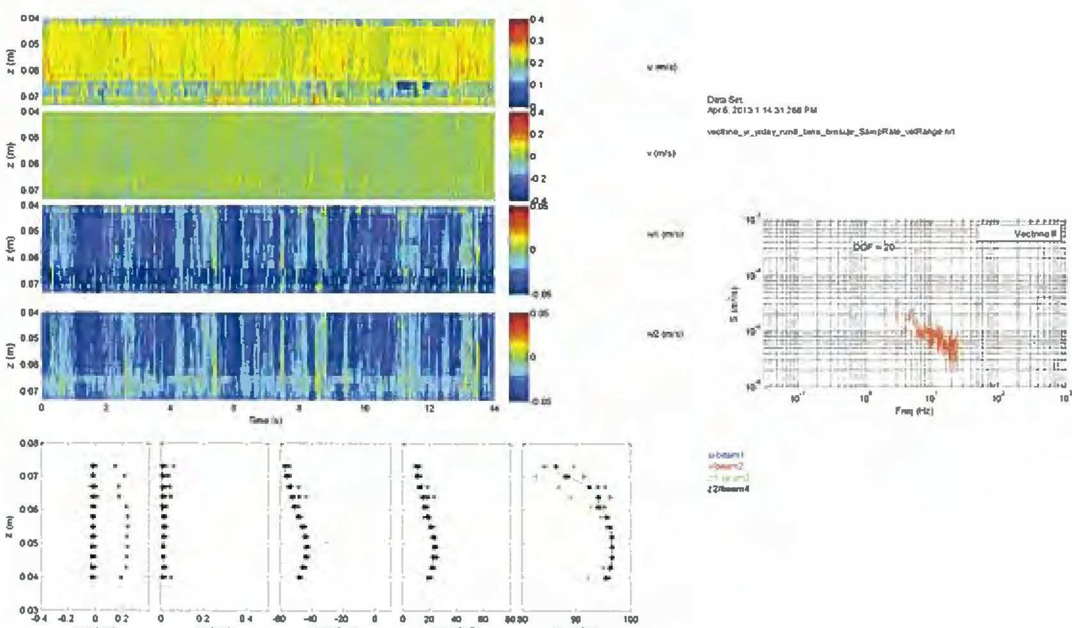
rms(uvw)
mean(Amp)
mean(SNR)
Mean(Cor)


u (m/s)
v (m/s)
w1 (m/s)
w2 (m/s)
Time (s)
Freq (Hz)
mean(uvw)
rms(uvw)
mean(Amp)
mean(SNR)
Mean(Cor)


z (m)
Time (s)
u (m/s)
v (m/s)
w1 (m/s)
w2 (m/s)
Data Set
Vectrino II
DOF = 20
Freq (Hz)
z2/beam4
mean(uvw)
rms(uvw)
mean(Amp)
mean(SNR)
Mean(Cor)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Time (s)
v (m/s)
Data Set
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Freq (Hz)
z2/beam4
mean(uvw)
rms(uvw)
mean(Amp)
mean(SNR)
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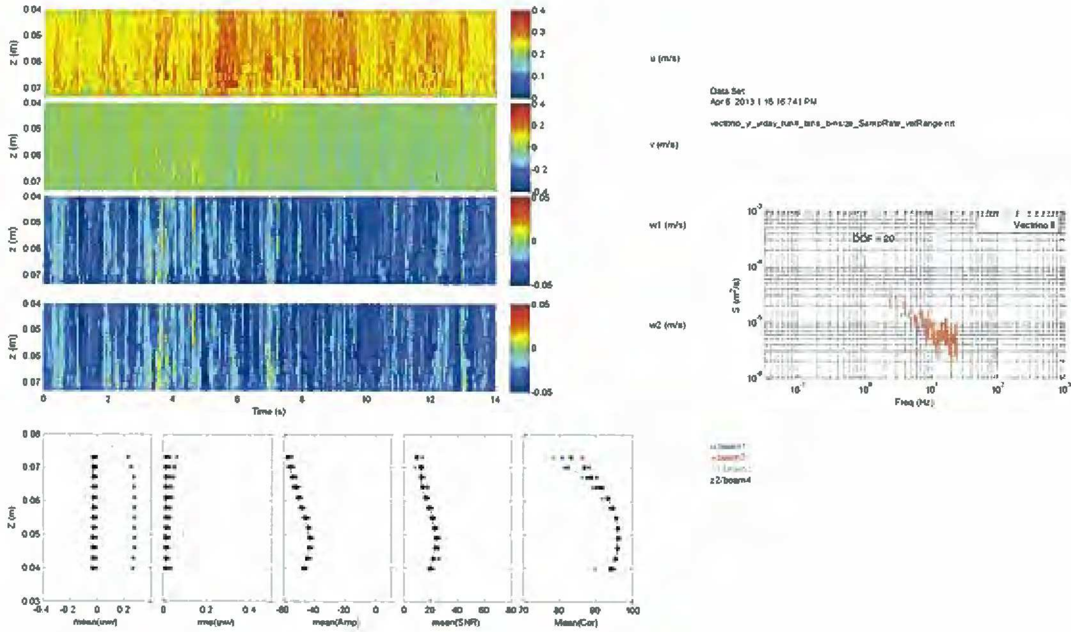
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v (m/s)
w1 (m/s)
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Time (s)
Data Set
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mean(uvw)
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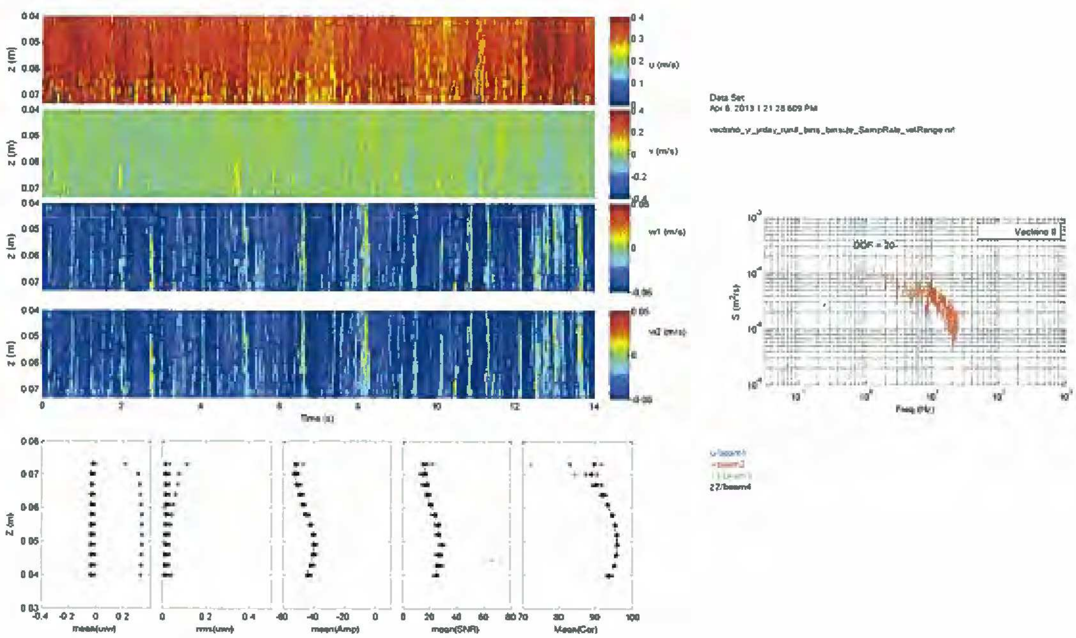
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Time (s)
Data Set
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Freq (Hz)
mean(uvw)
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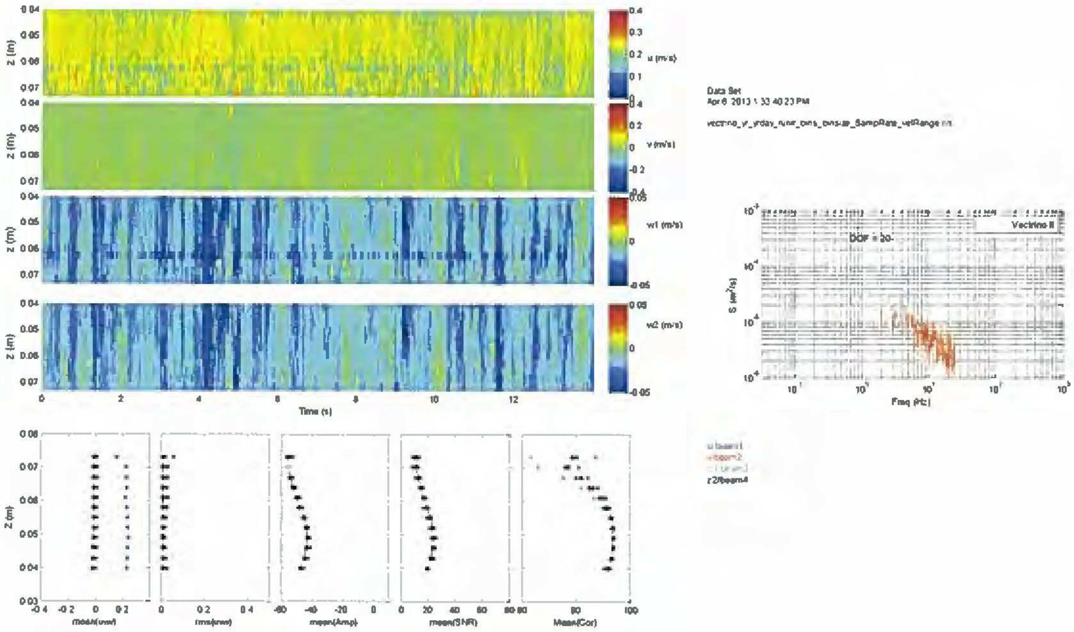
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Data Set
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mean(SNR)
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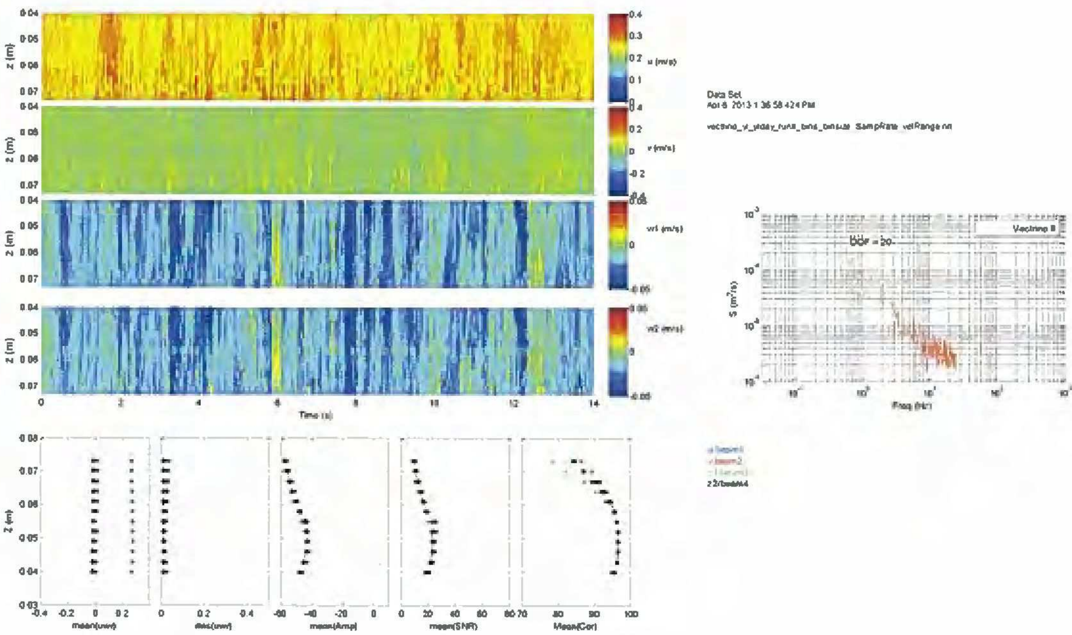
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Data Set
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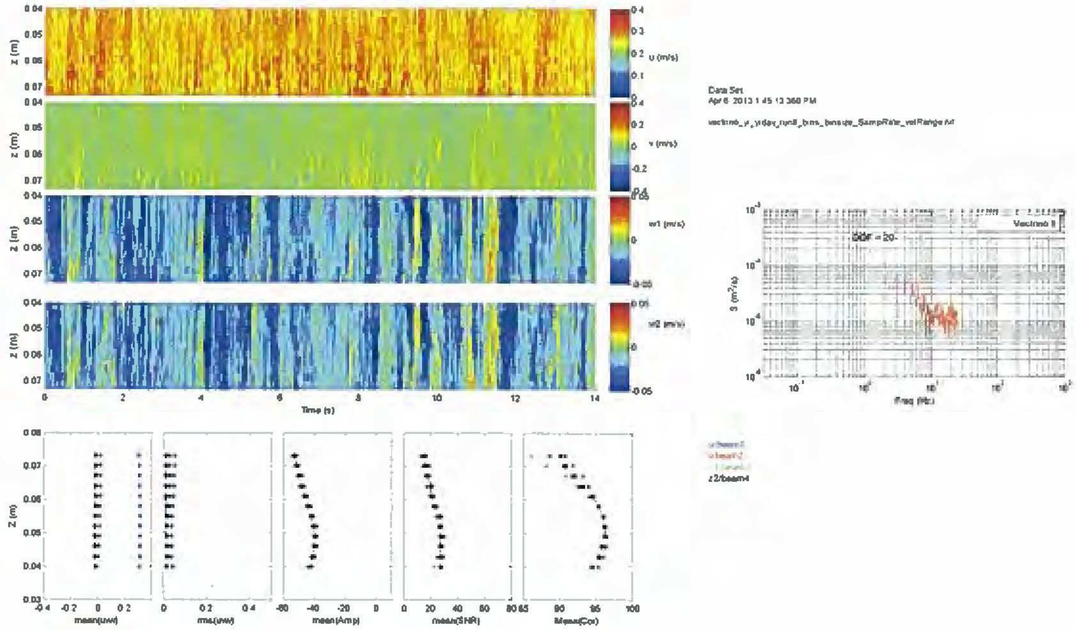
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Time (s)
Data Set
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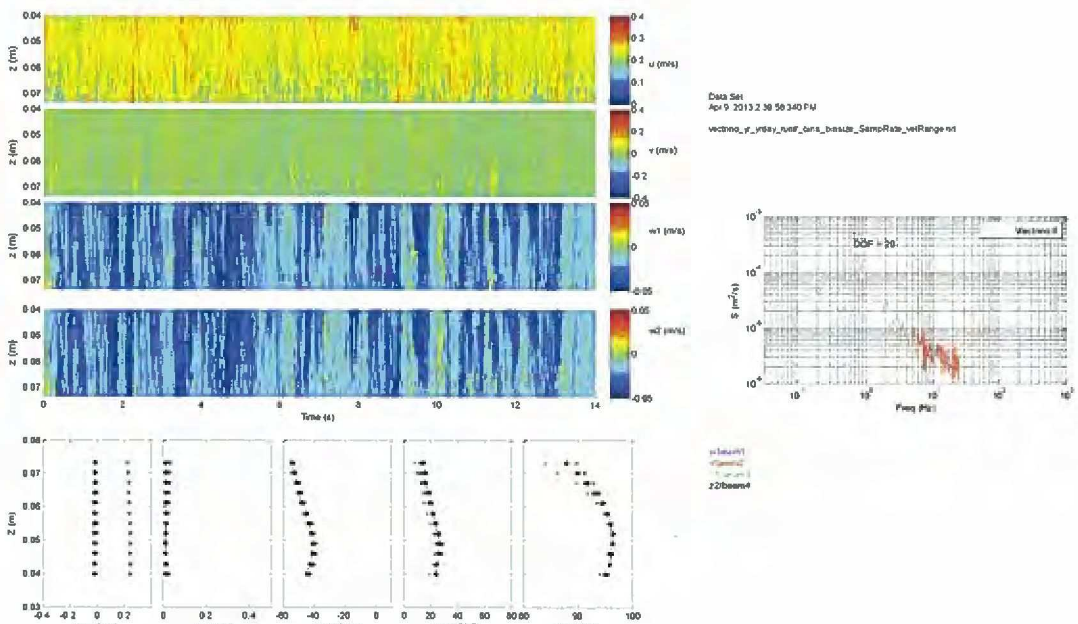
Vectrino II
Freq (Hz)
mean(uvw)
rms(uvw)
mean(Amp)
mean(SNR)
Mean(Cor)
z2/beam4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w2 (m/s)
Time (s)
Data Set
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Vectrino II
Freq (Hz)
mean(uvw)
rms(uvw)
mean(Amp)
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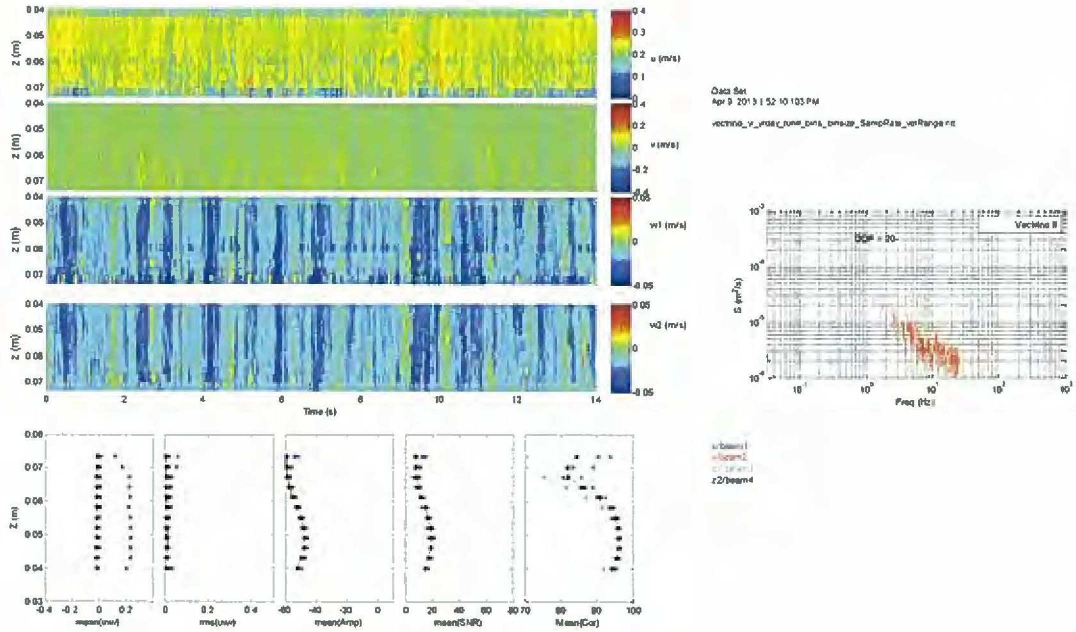
Mean(Cor)
z2/beam4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w2 (m/s)
Time (s)
Data Set
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Vectrino II
Freq (Hz)
mean(uvw)
rms(uvw)
mean(Amp)
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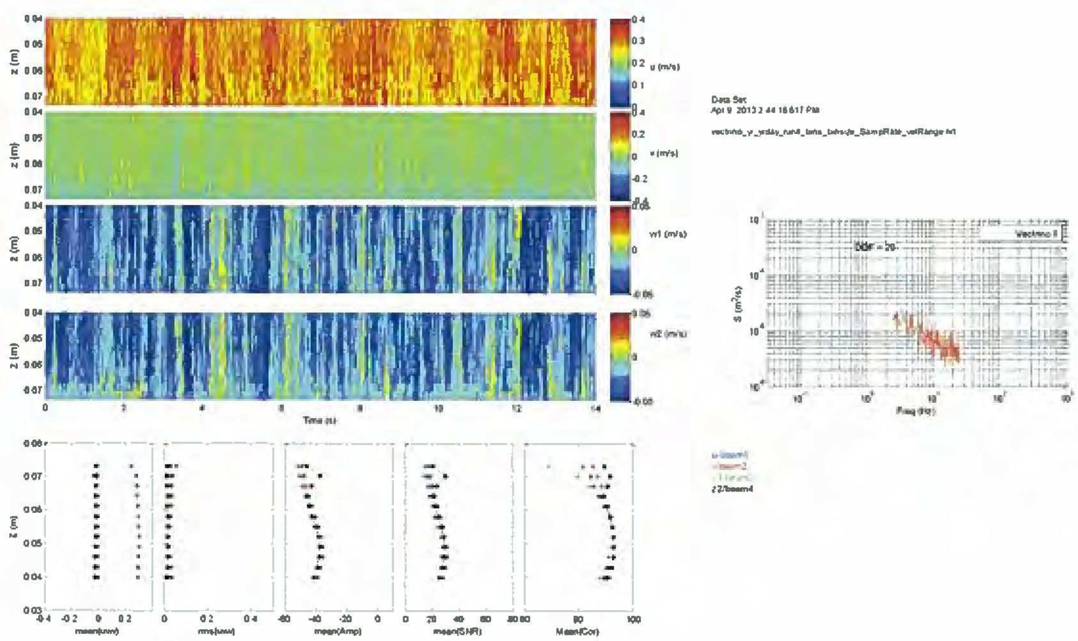
Mean(Cor)
z2/beam4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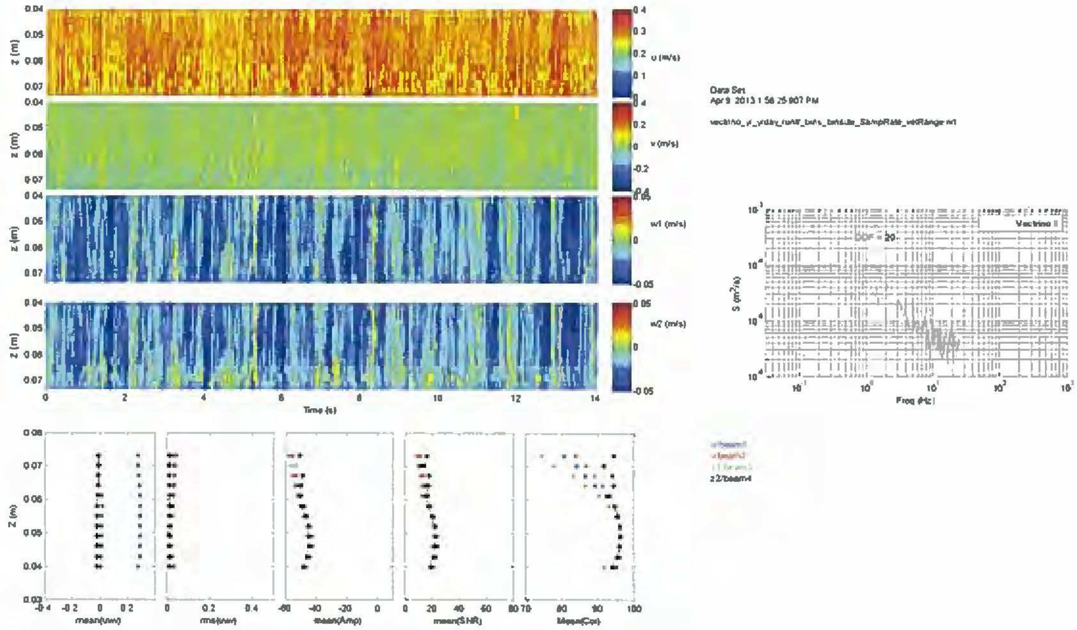
v (m/s)
w1 (m/s)
w2 (m/s)
Time (s)
Data Set
DOF = 20
Vectrino II
Freq (Hz)
mean(uvw)
rms(uvw)
mean(Amp)
mean(SNR)
Mean(Cor)
z2/beam4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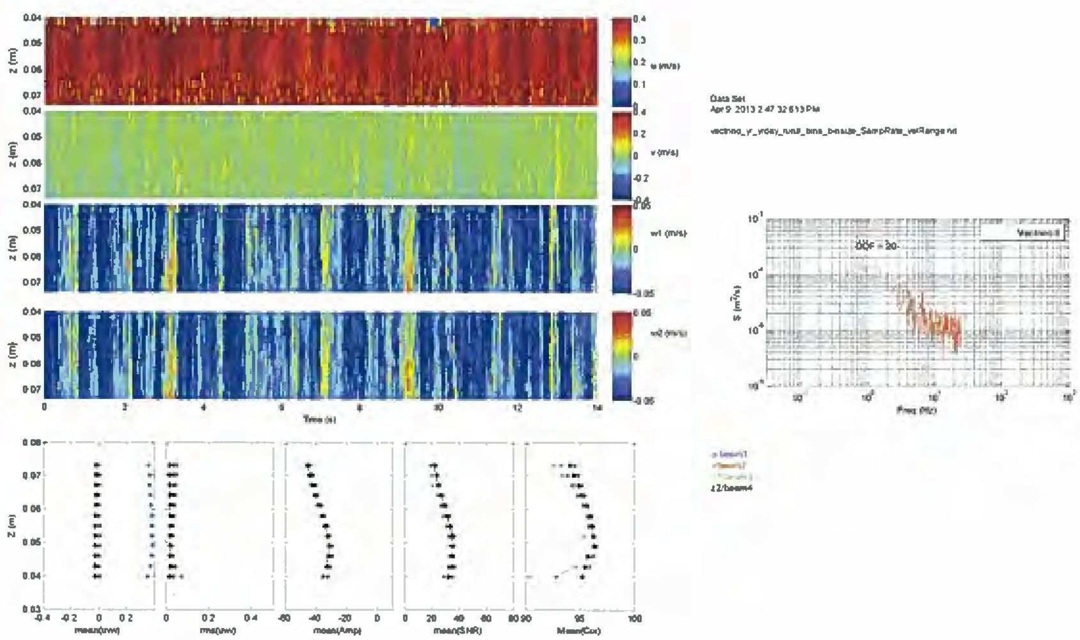
v (m/s)
w1 (m/s)
w2 (m/s)
z (m)
Time (s)
Data Set
Apr 9 2013 1 58 25 907 PM
Vectrino II
DOF = 20
S (m²/s)
Freq (Hz)
Z (m)
mean(uvw)
rms(uvw)
mean(Amp)
mean(SNR)
Mean(Cor)
z2/beam4


u (m/s)
v (m/s)
w1 (m/s)
w2 (m/s)
z (m)
Time (s)
Data Set
Apr 9 2013 2 47 32 613 PM
Vectrino II
DOF = 20
S (m²/s)
Freq (Hz)
Z (m)
mean(uvw)
rms(uvw)
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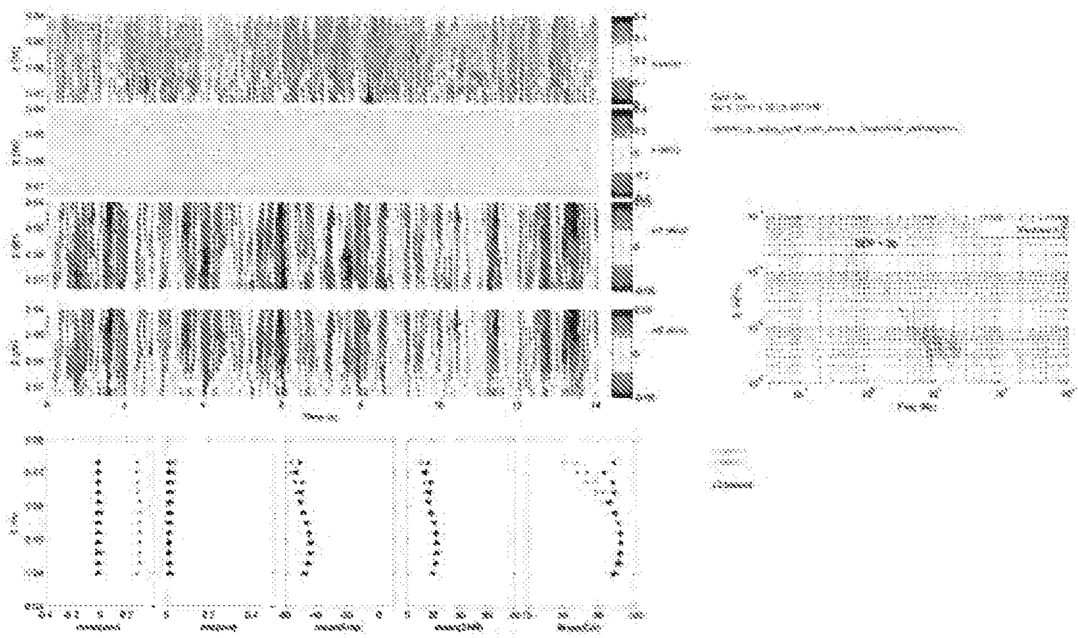
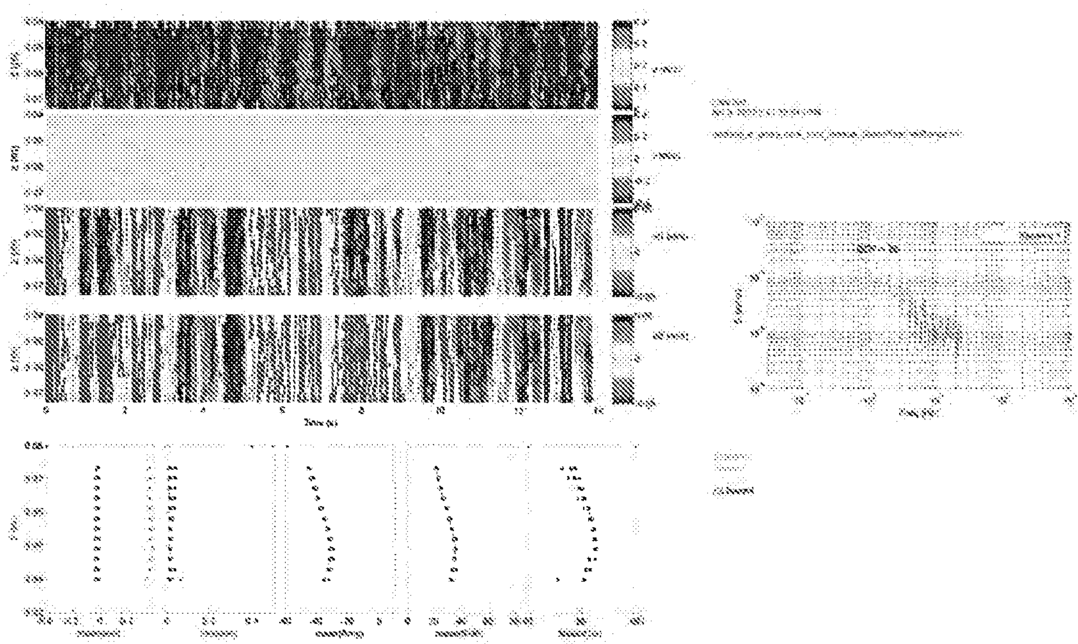
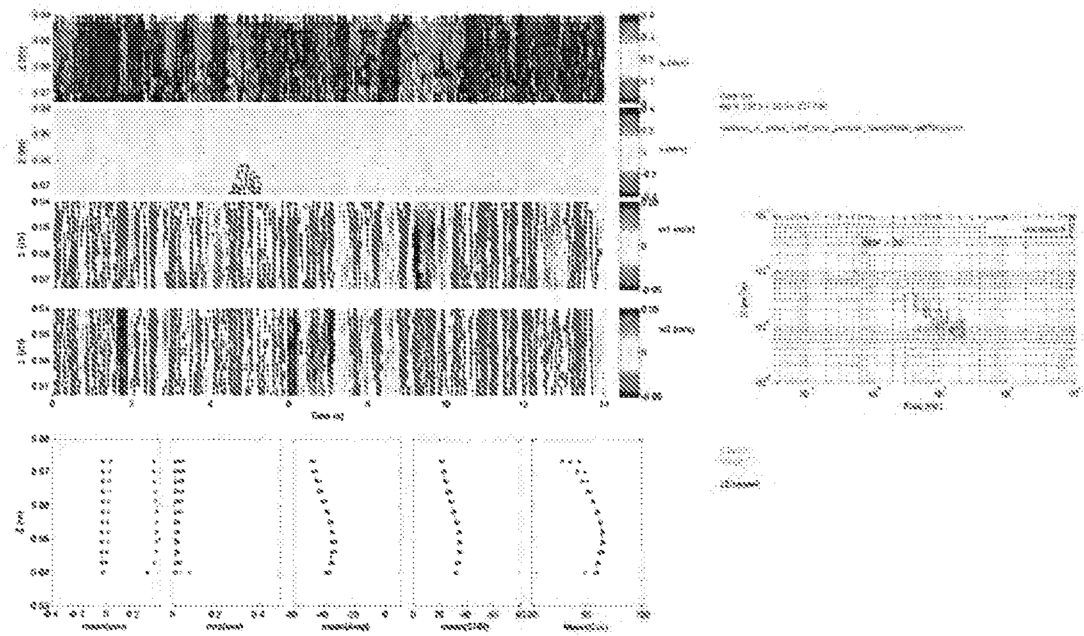
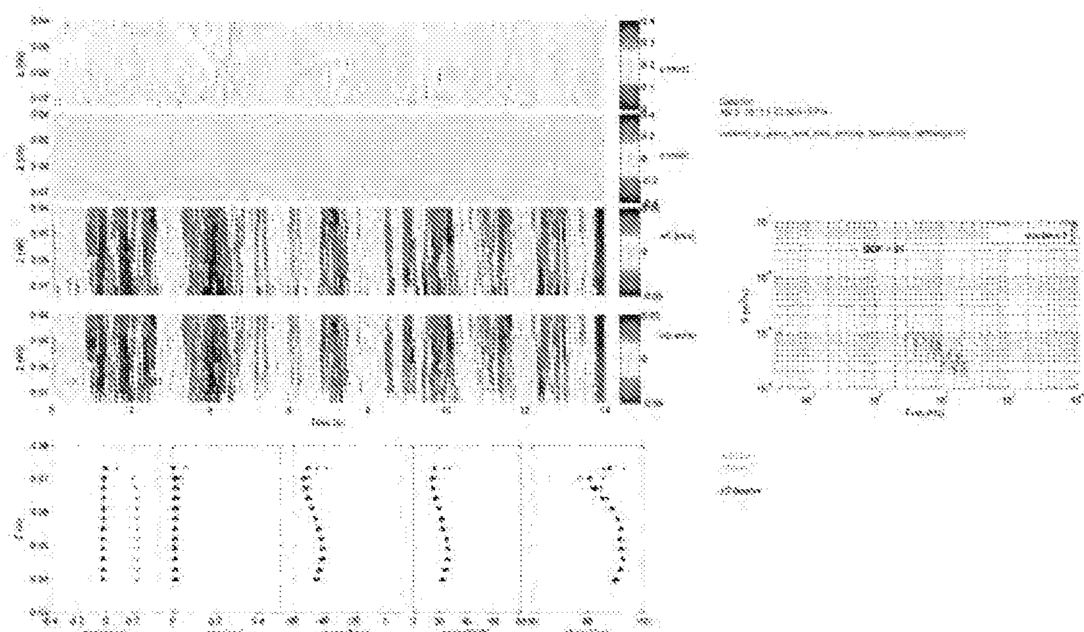
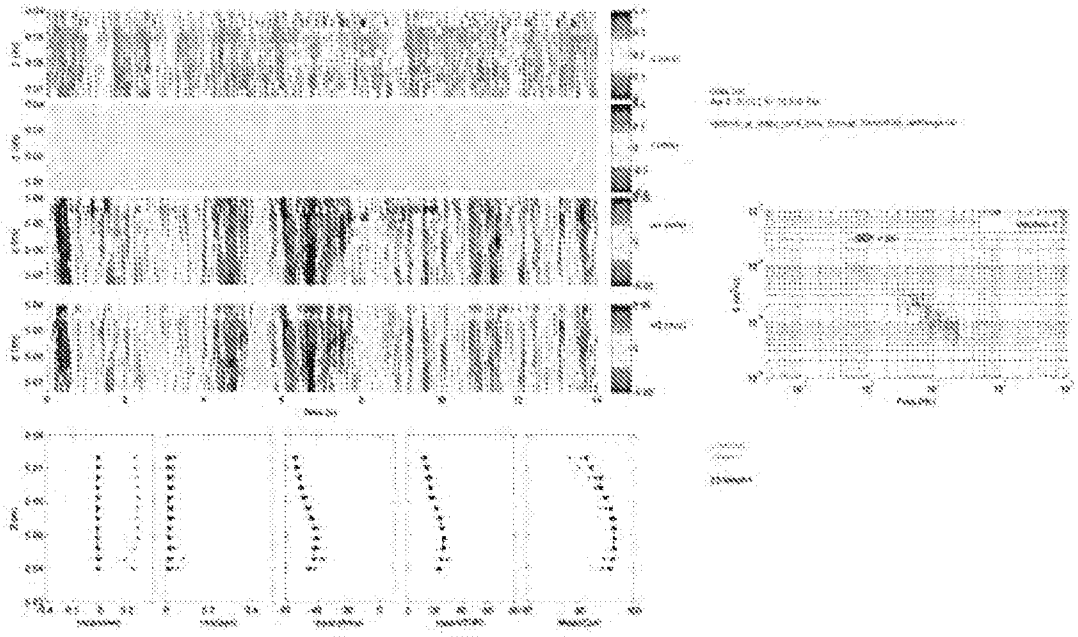
mean(SNR)
Mean(Cor)
z2/beam4

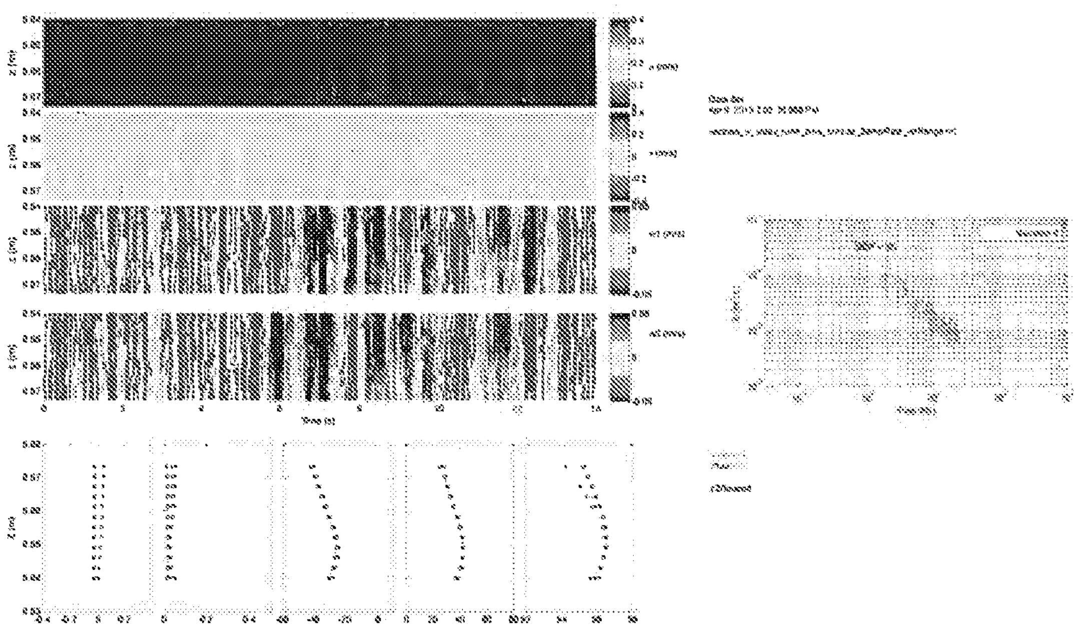


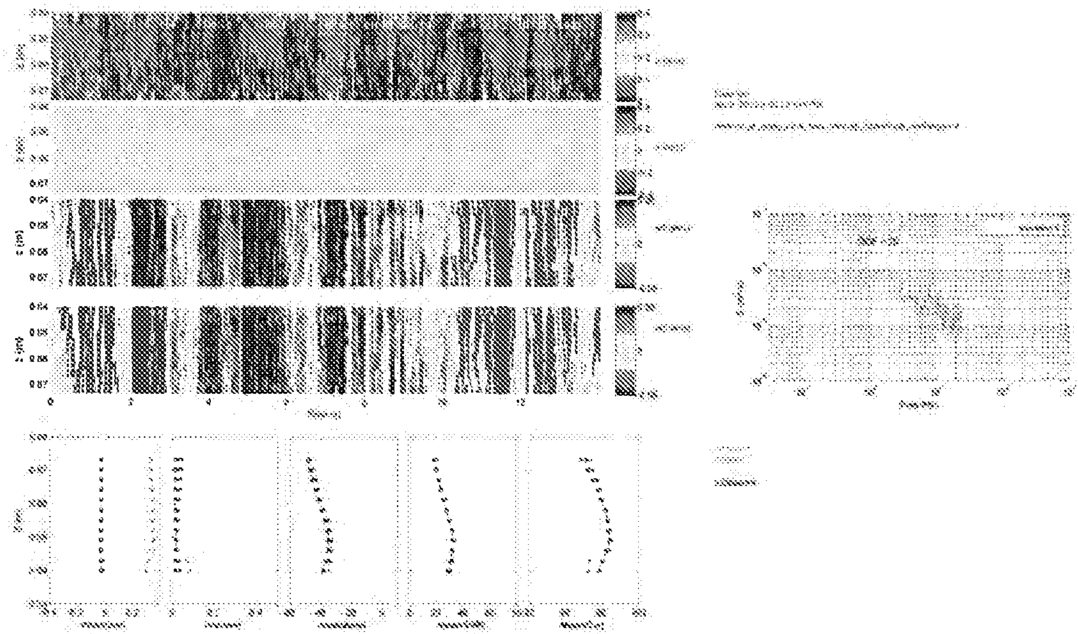


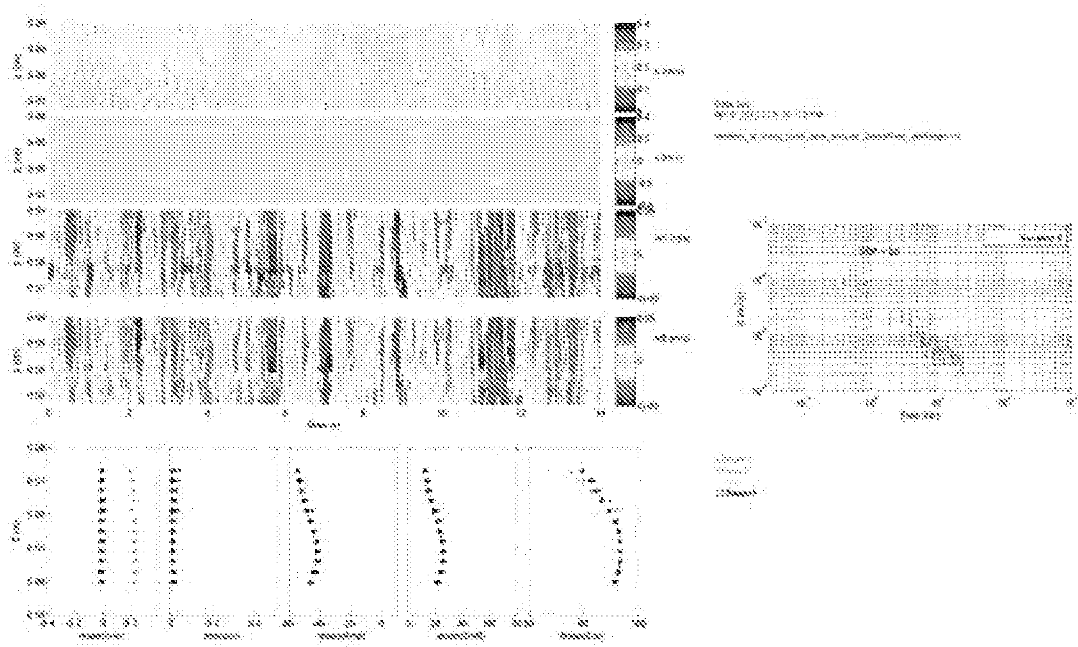


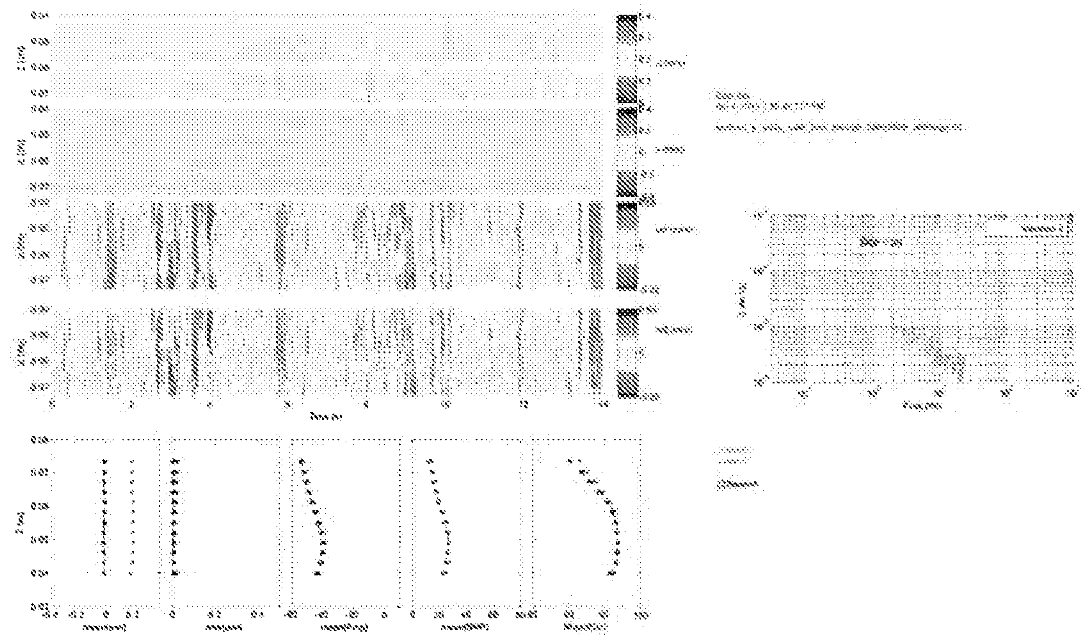


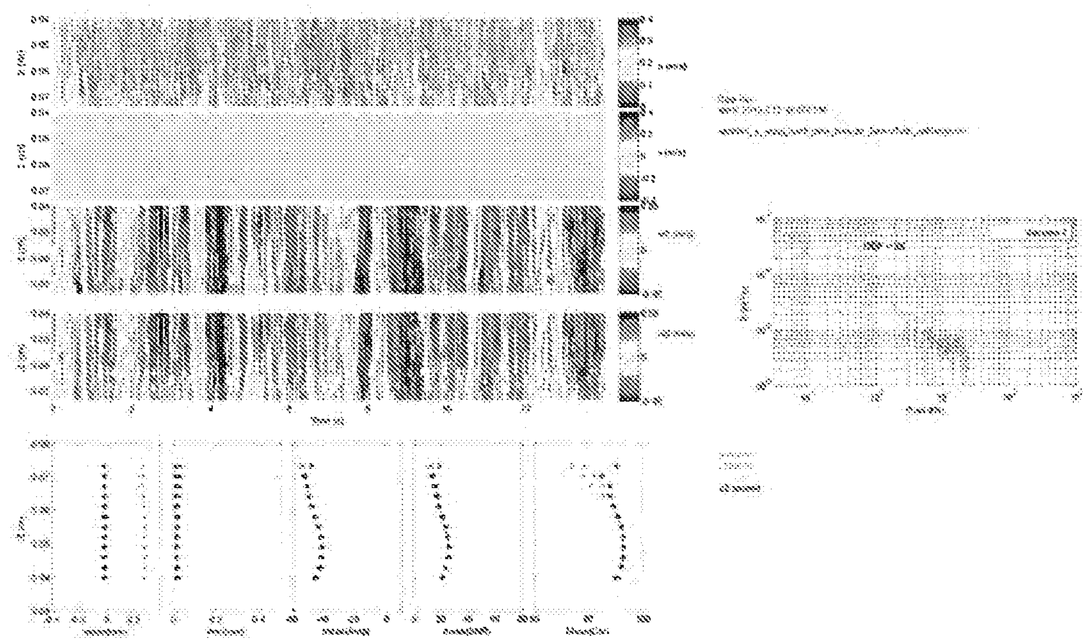


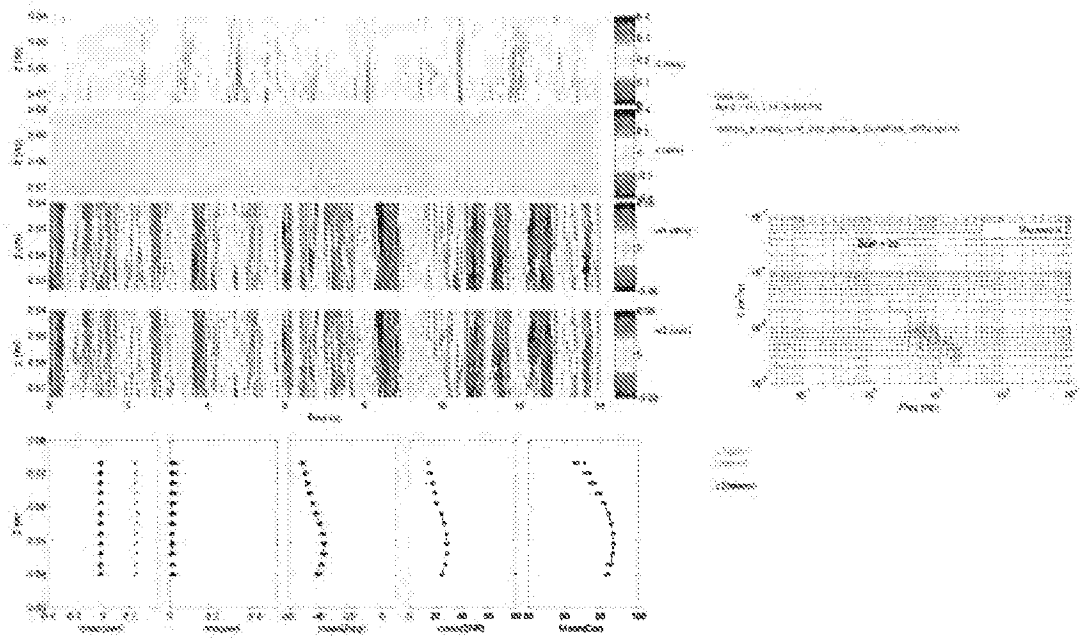


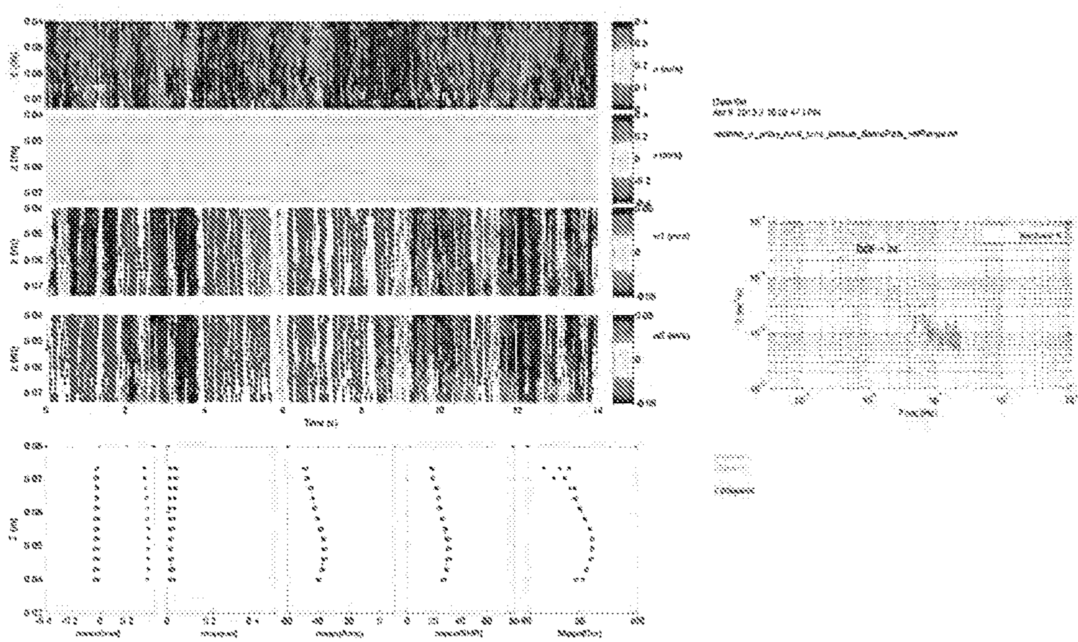


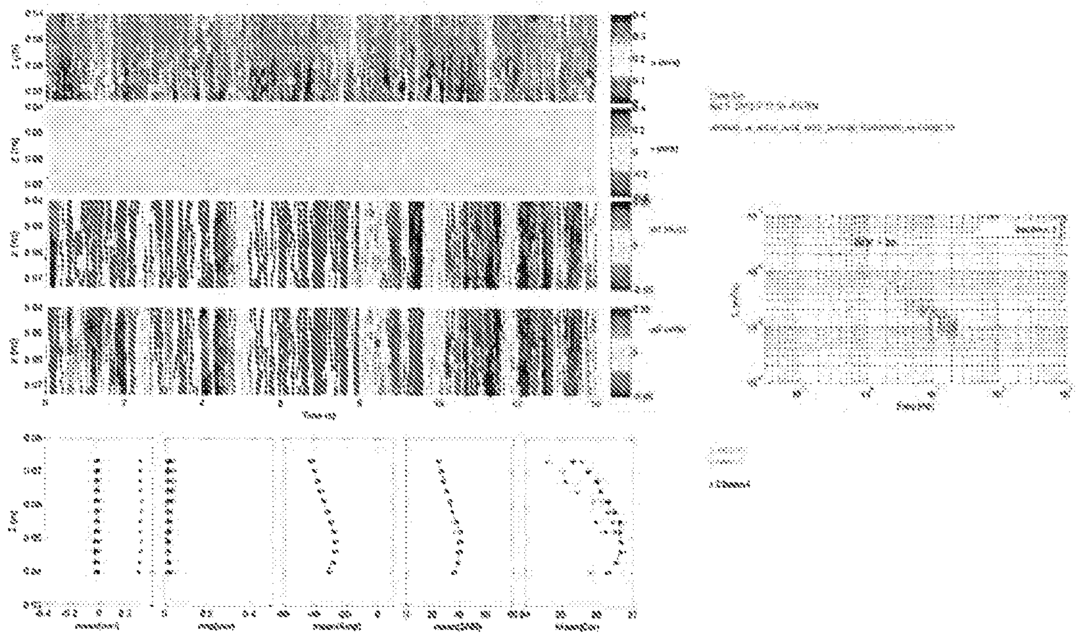


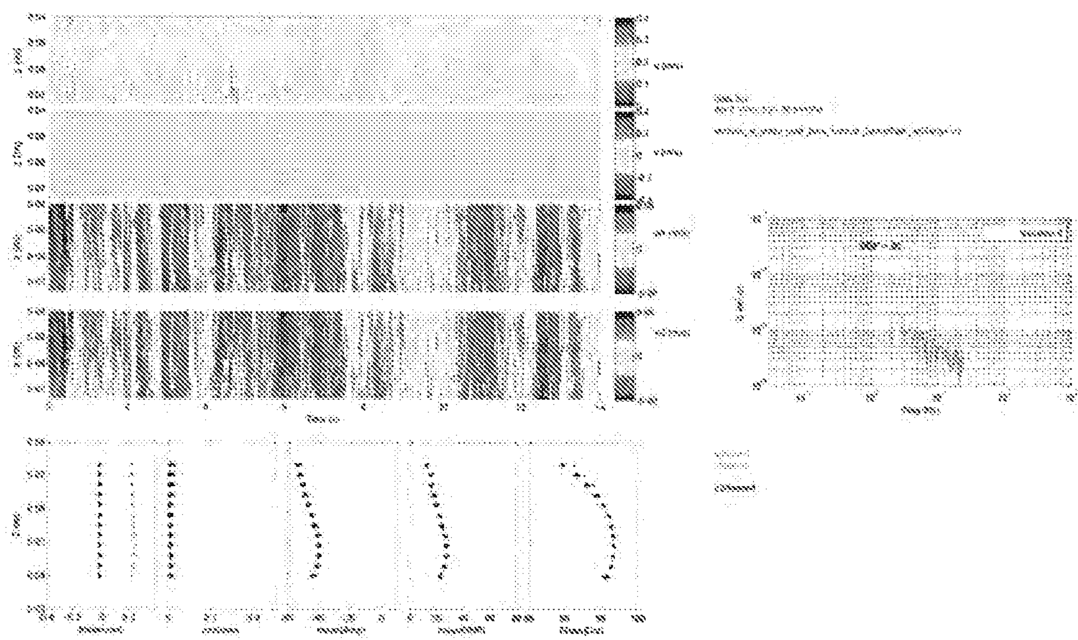


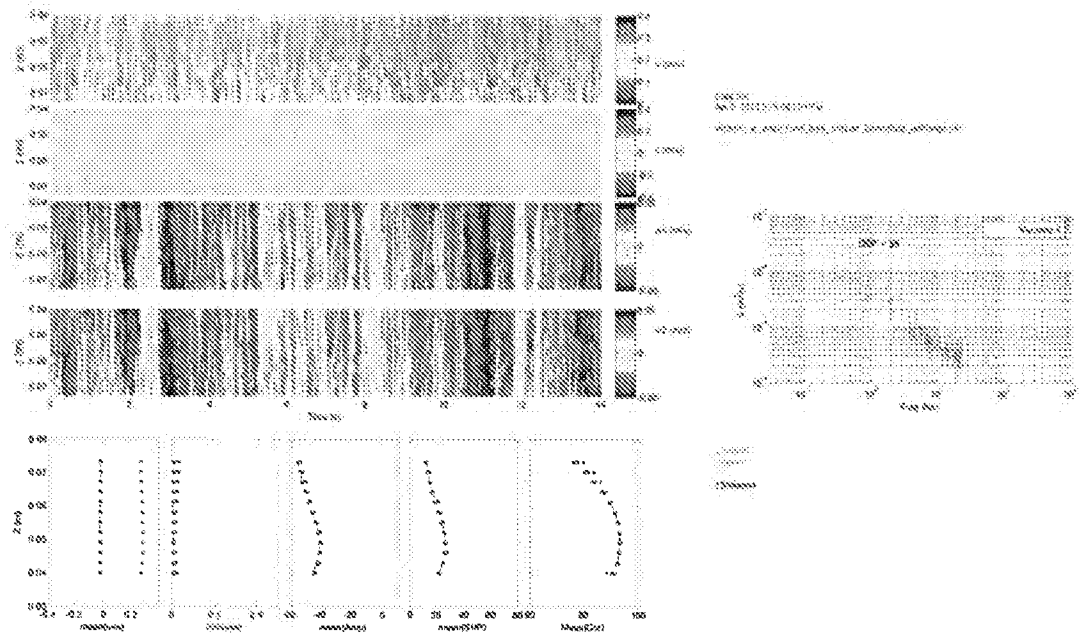


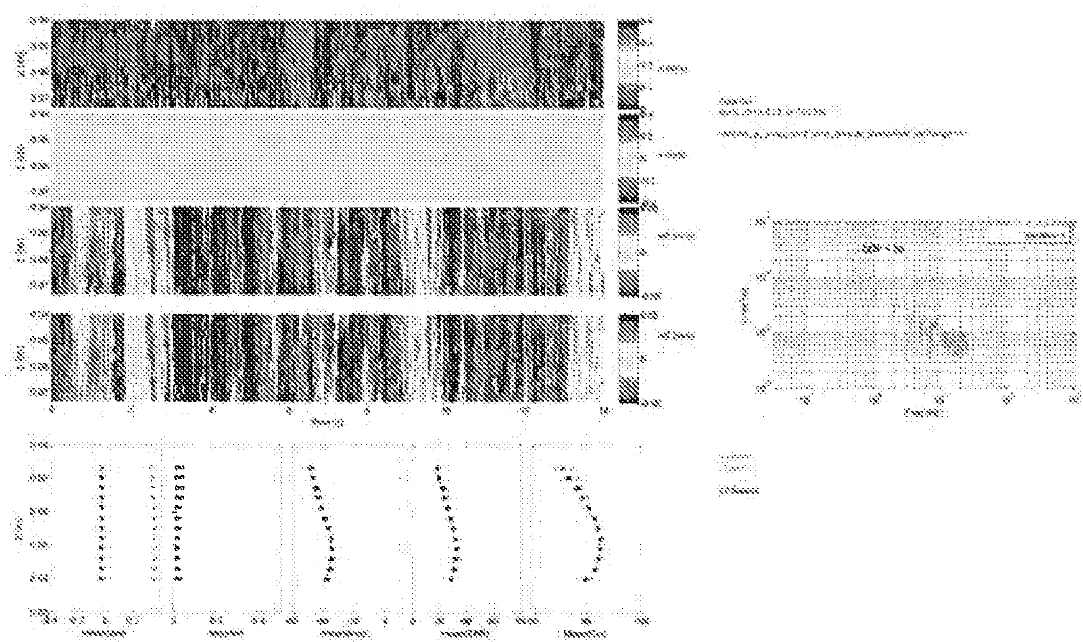


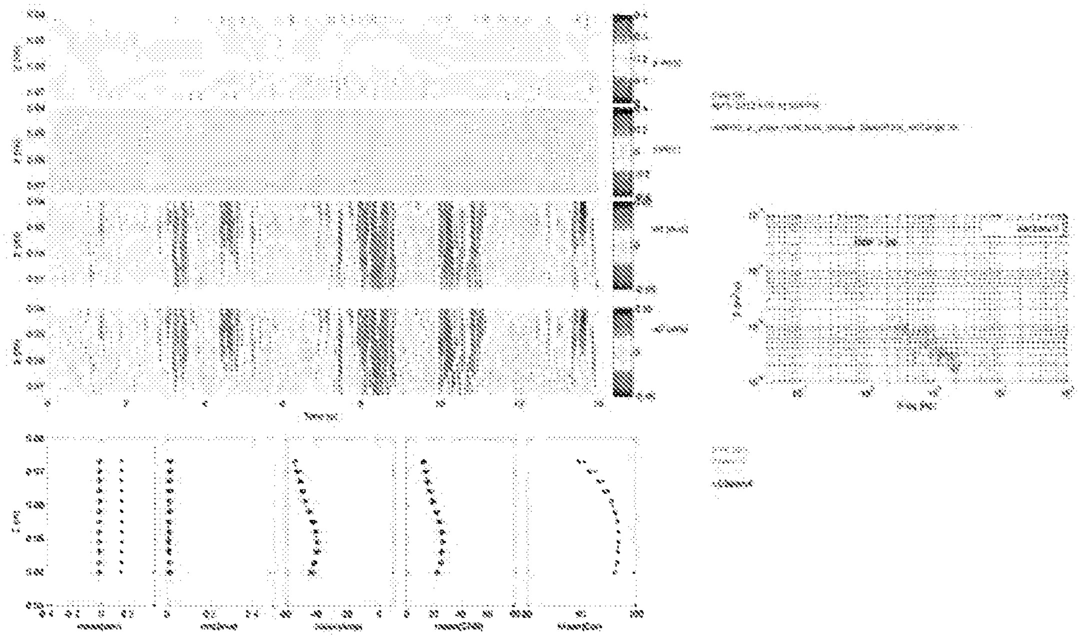


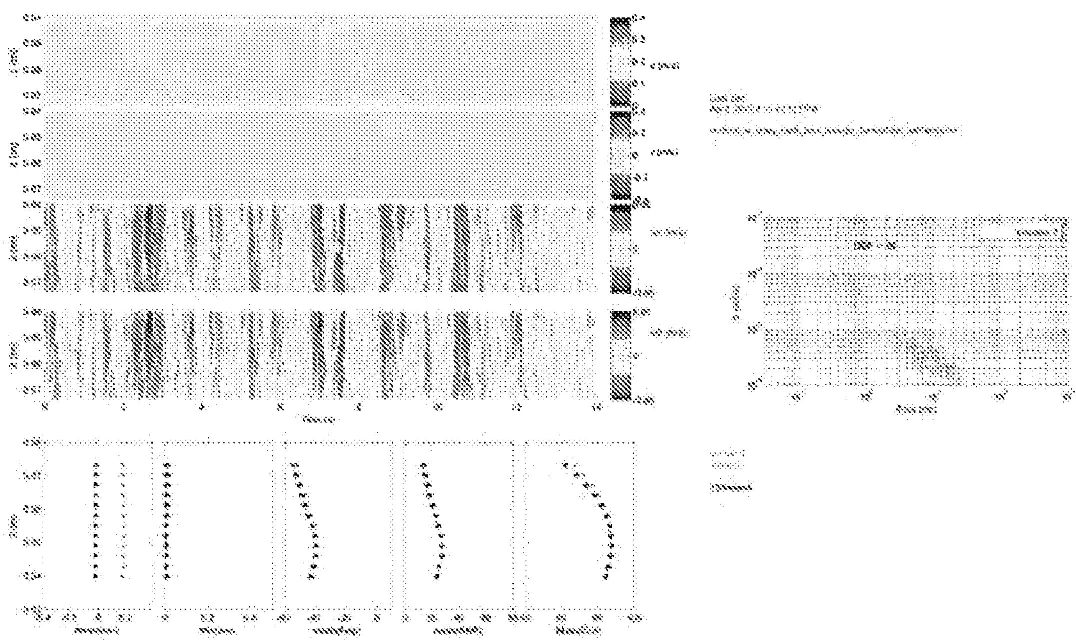


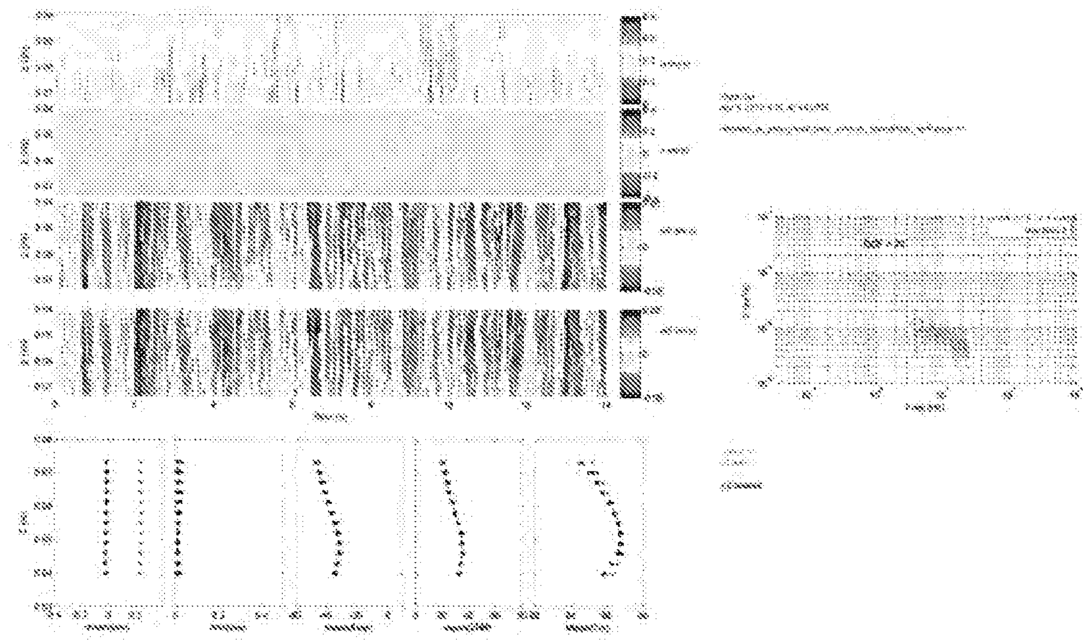


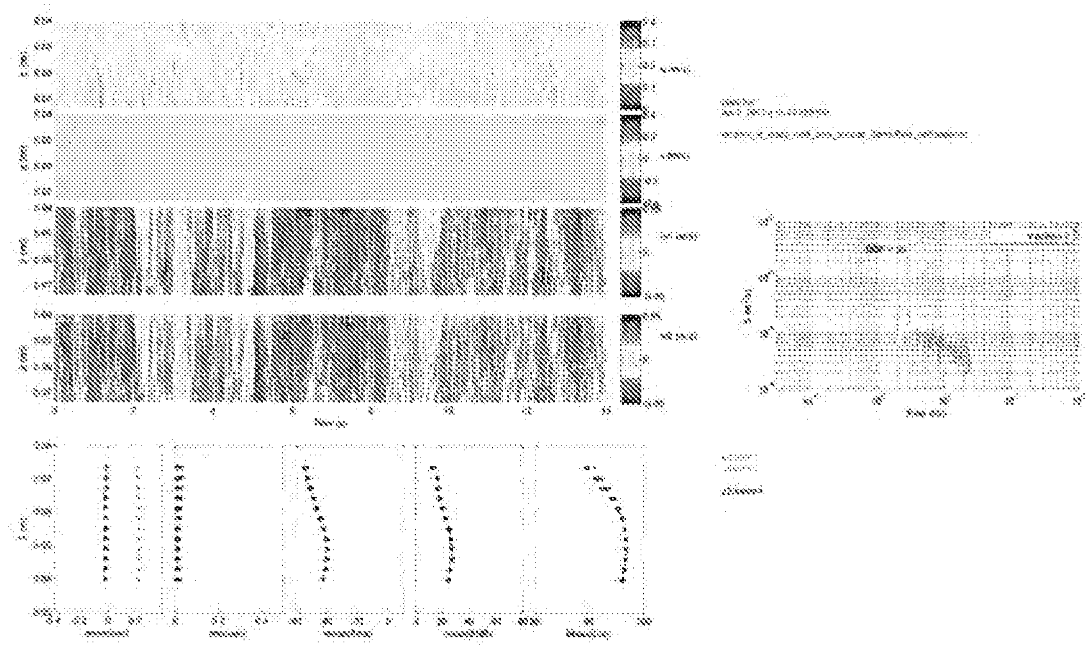


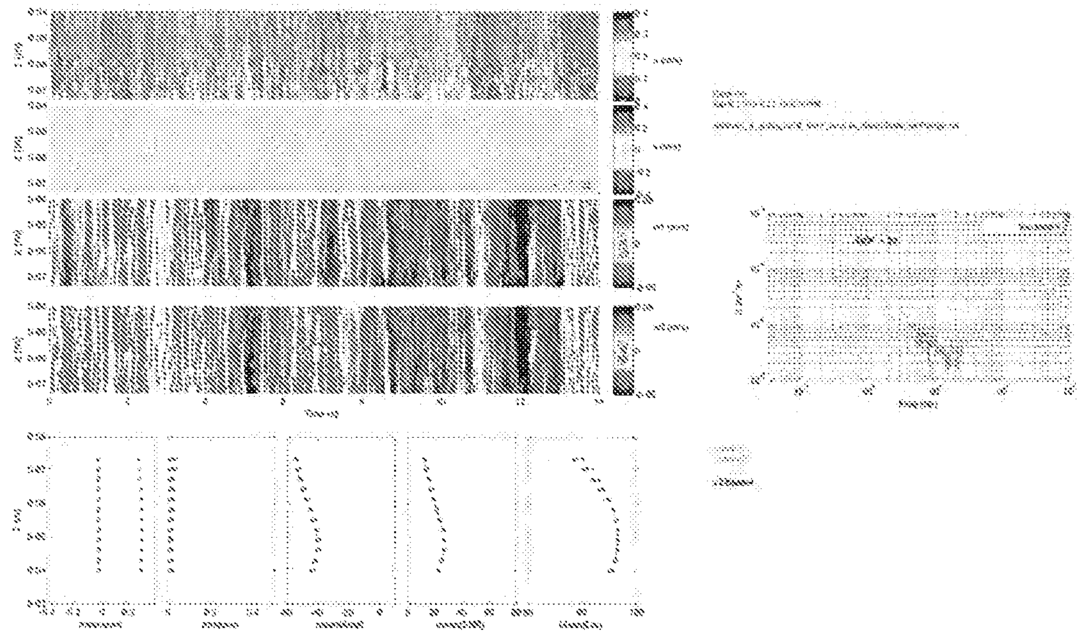


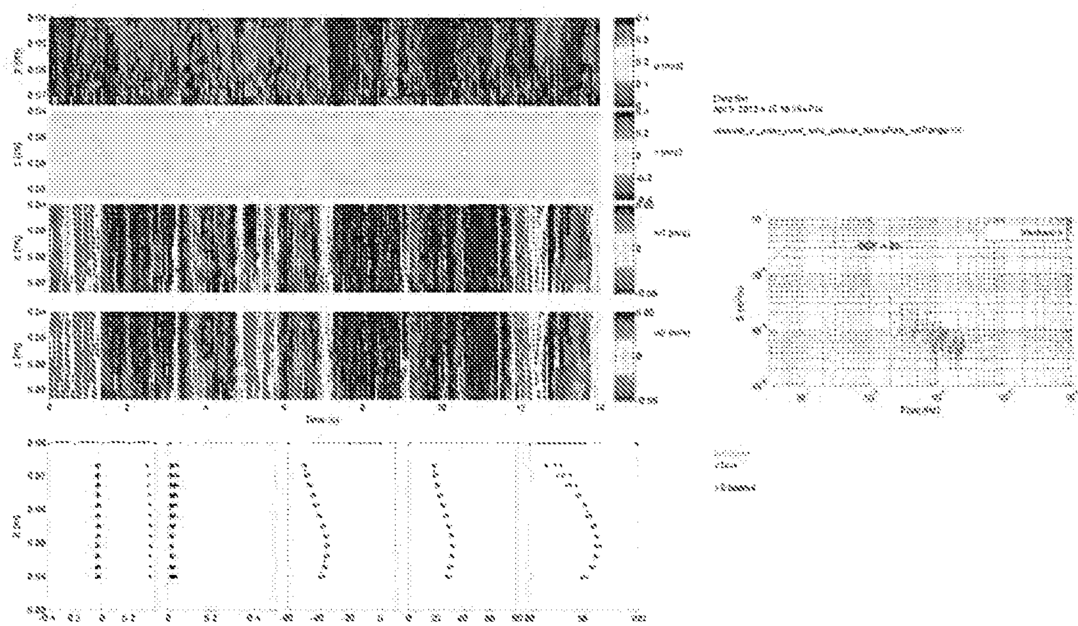


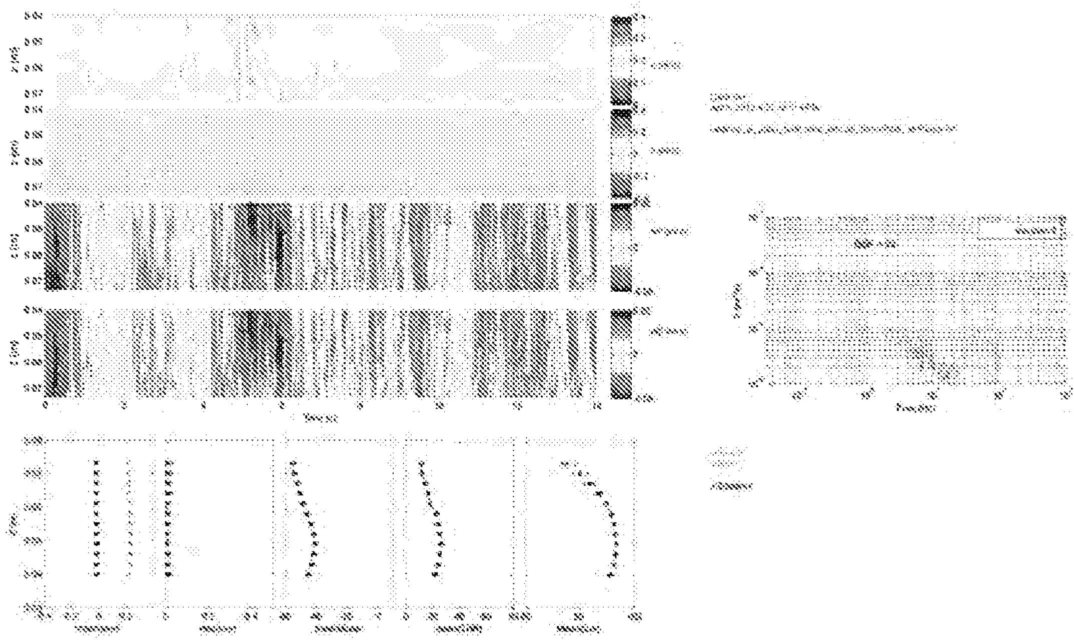


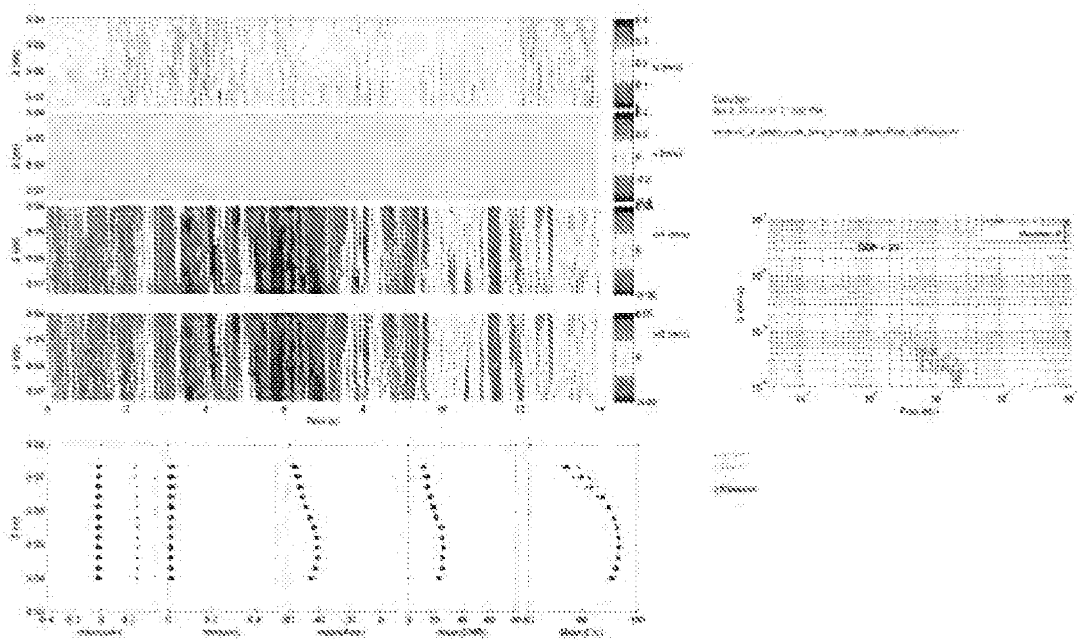


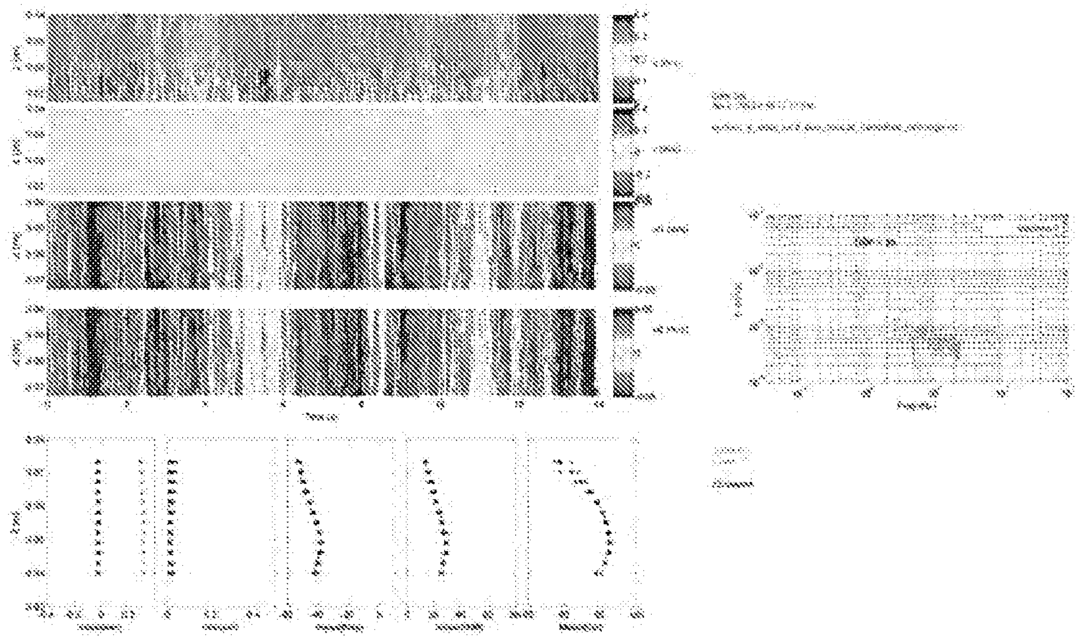


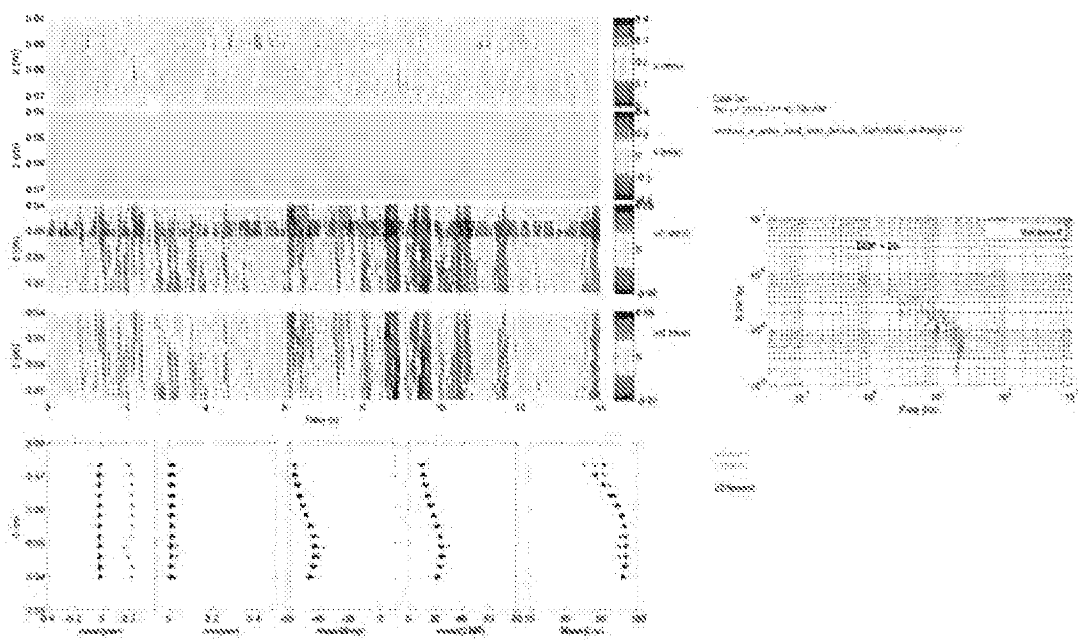


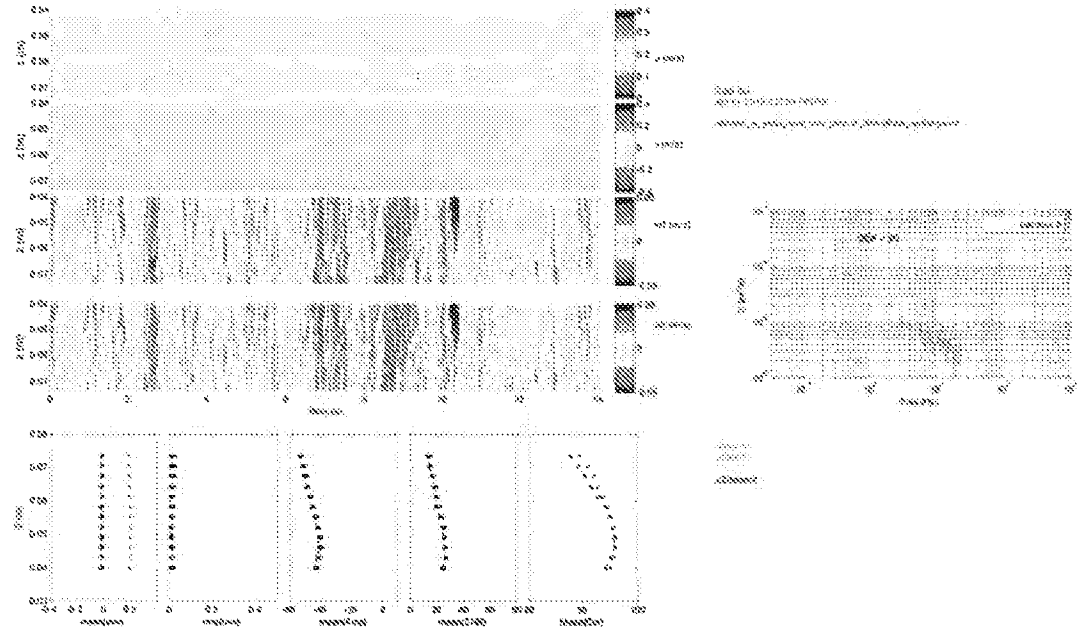


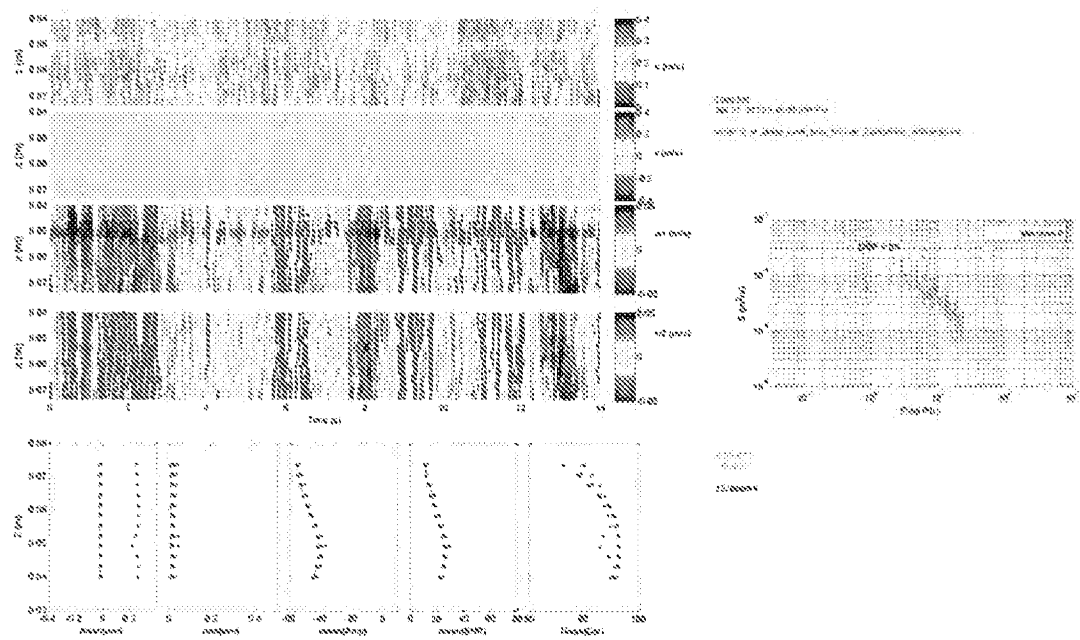


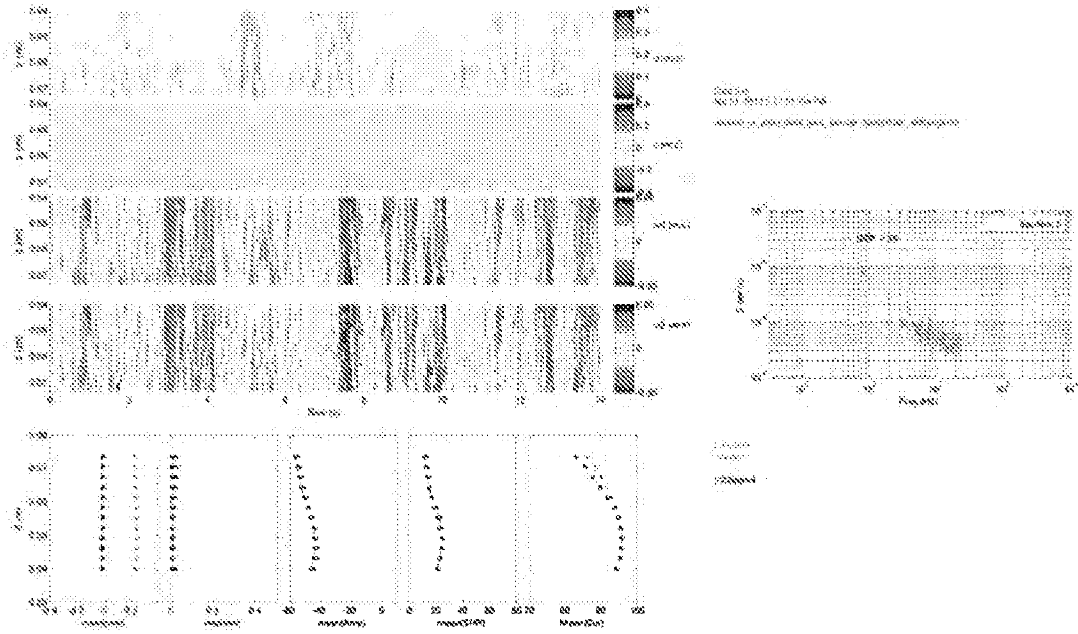


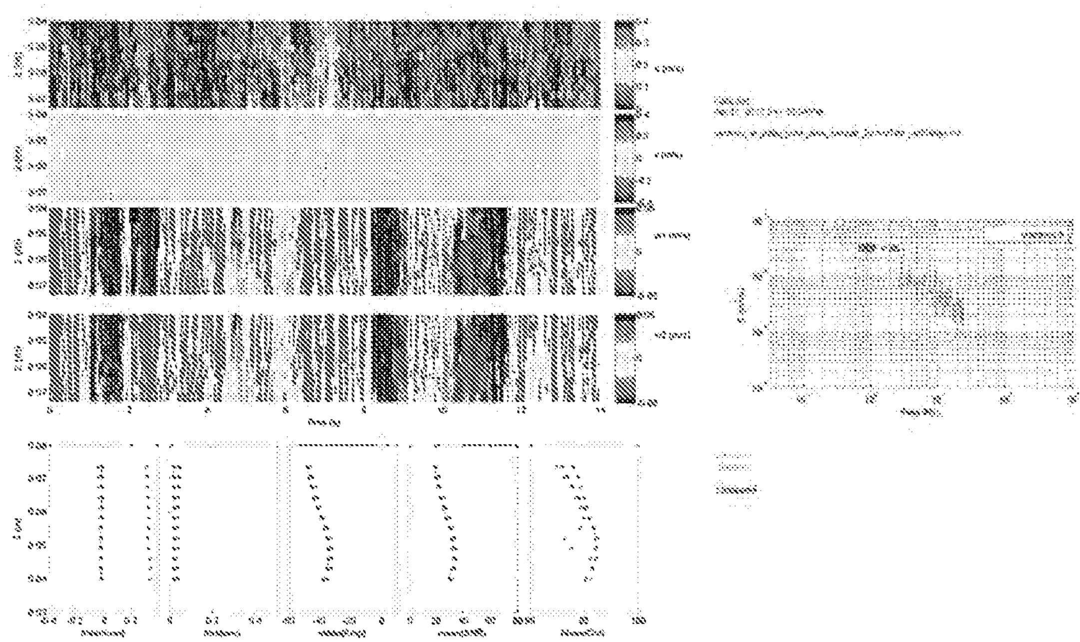


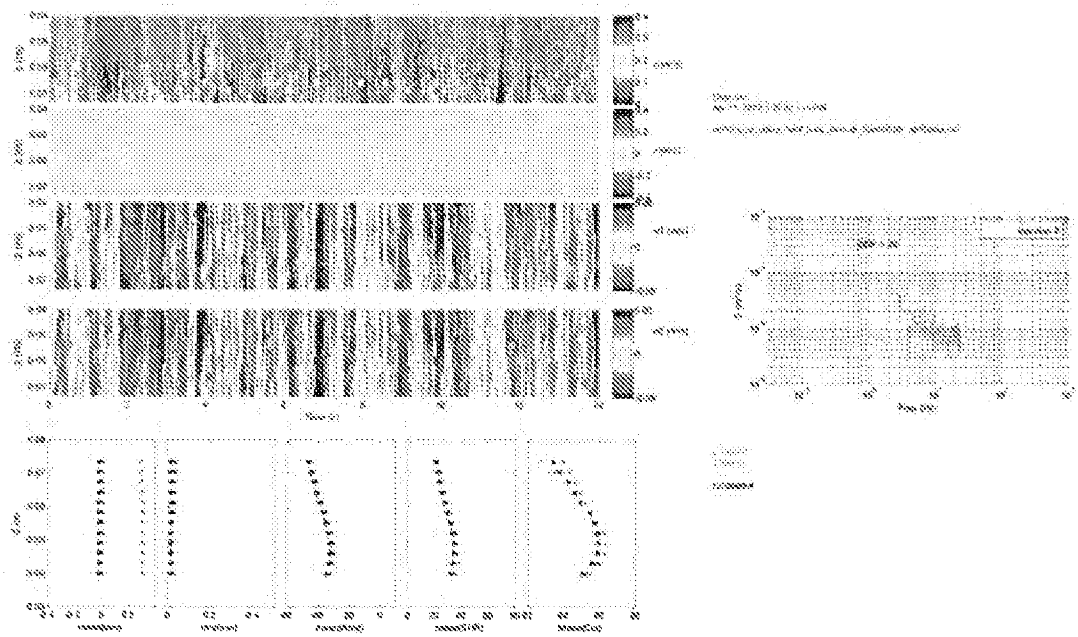


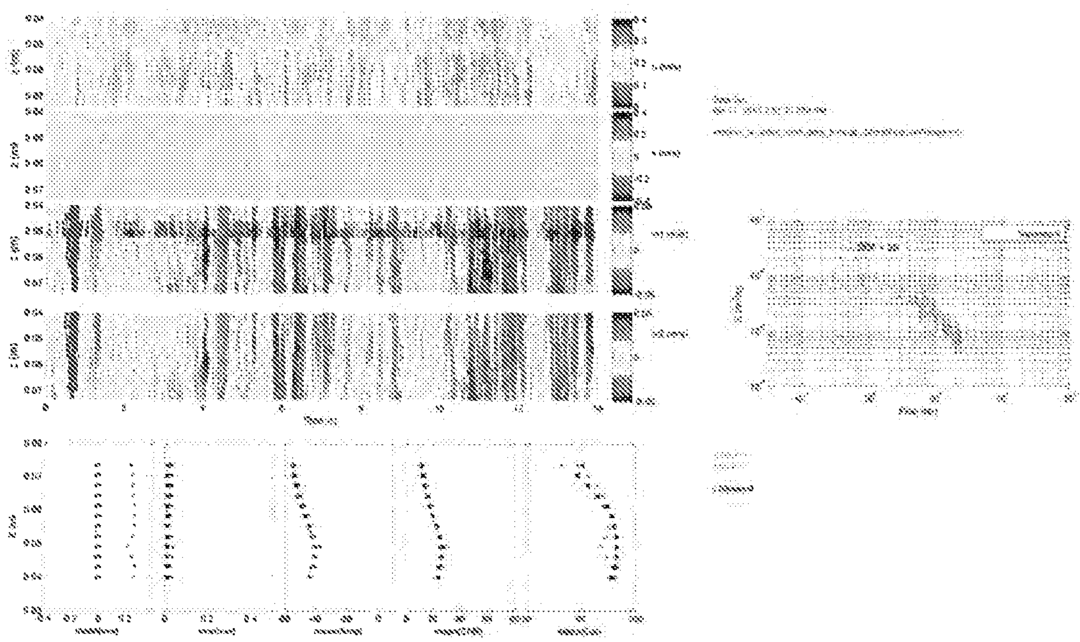


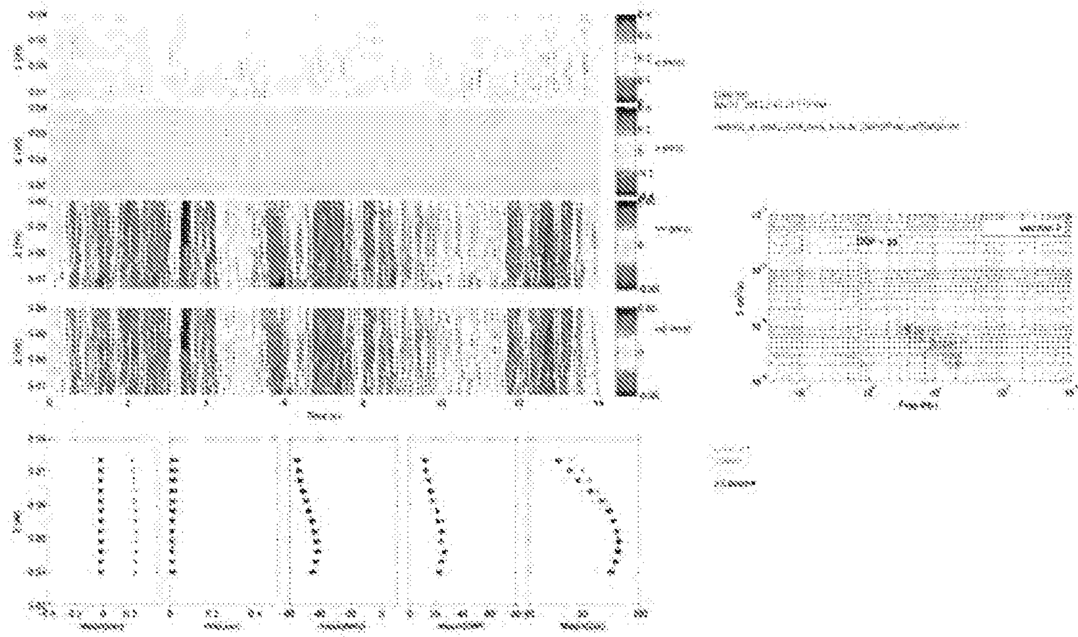


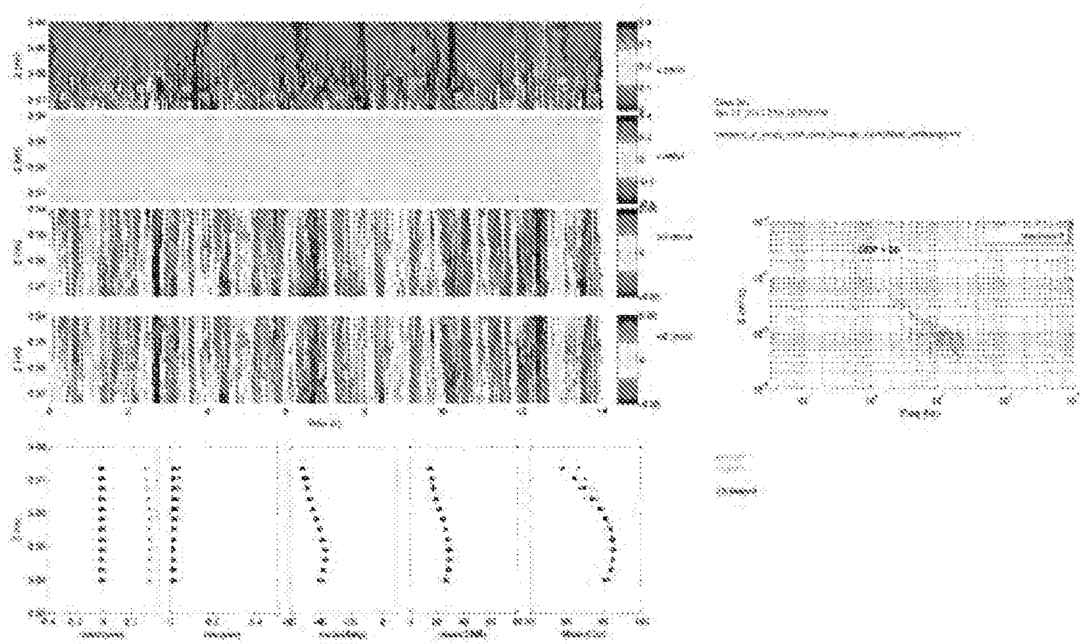


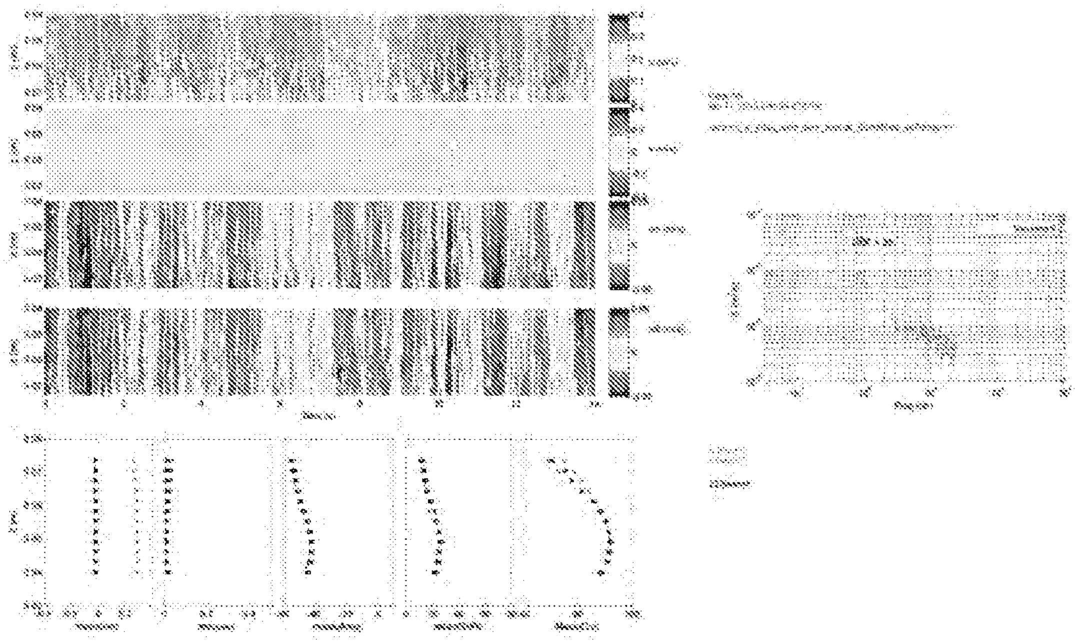


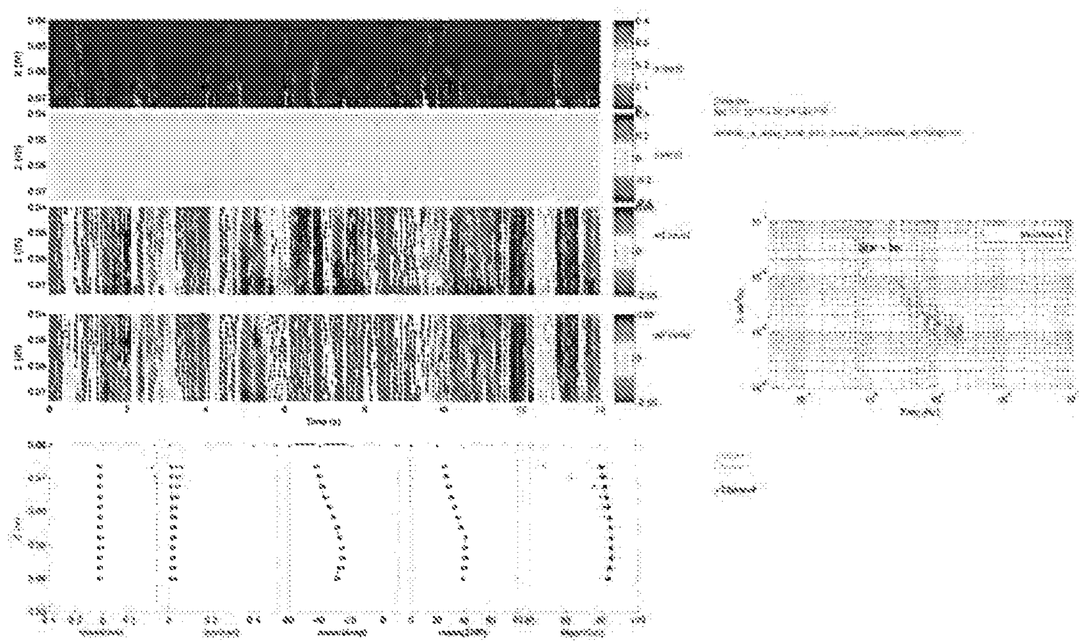


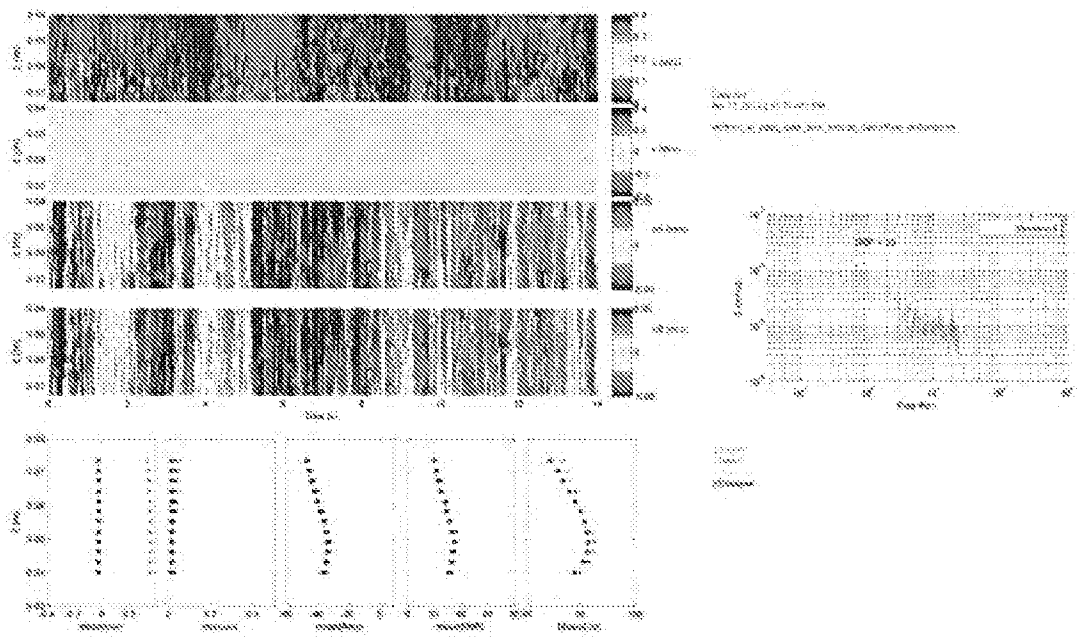


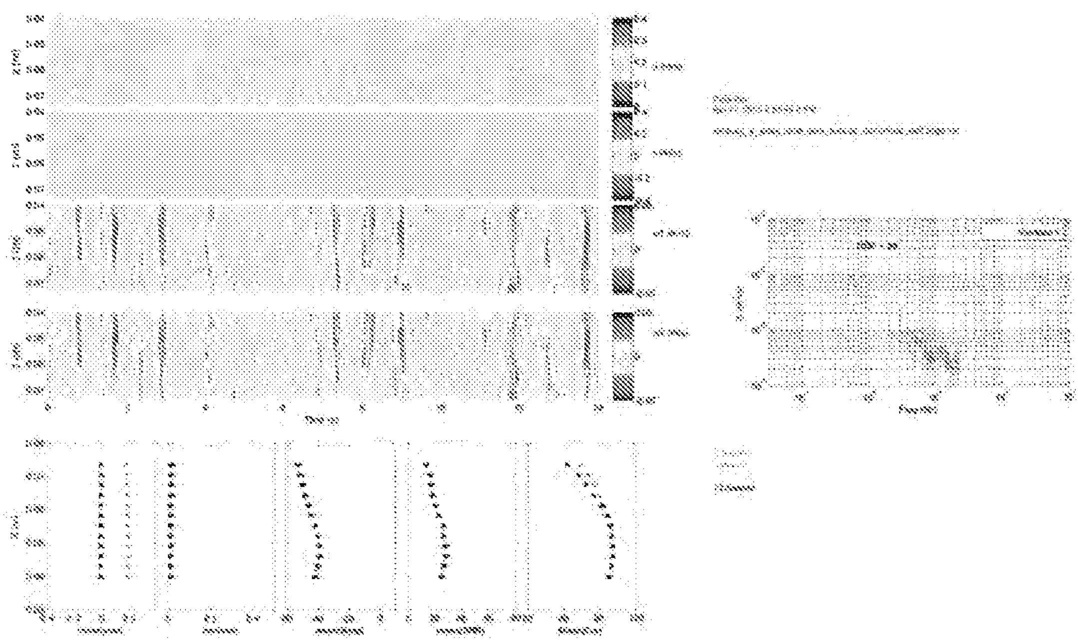


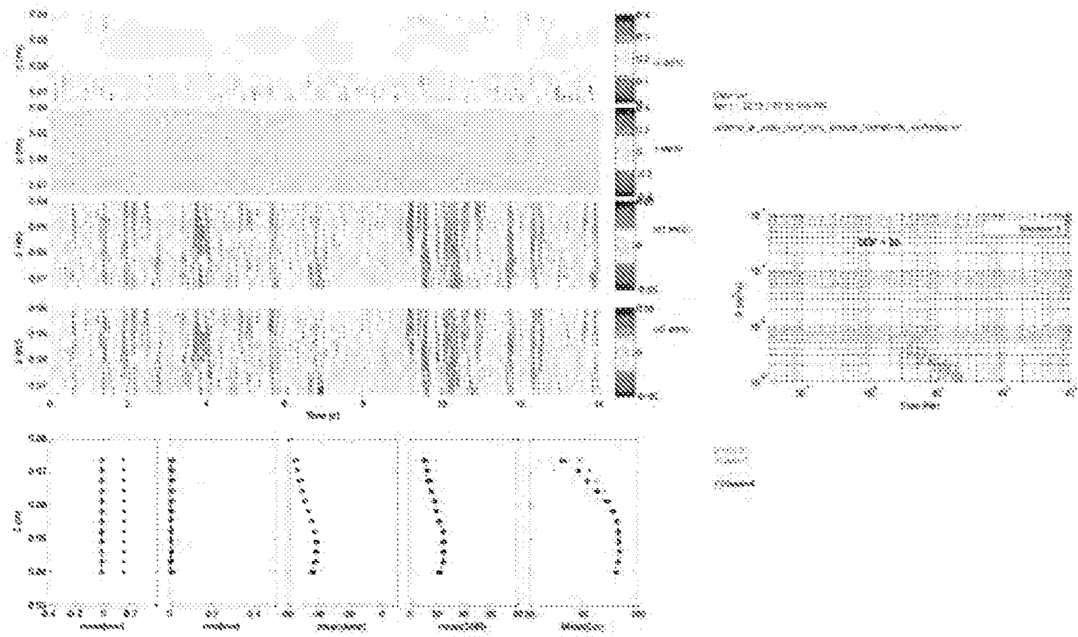


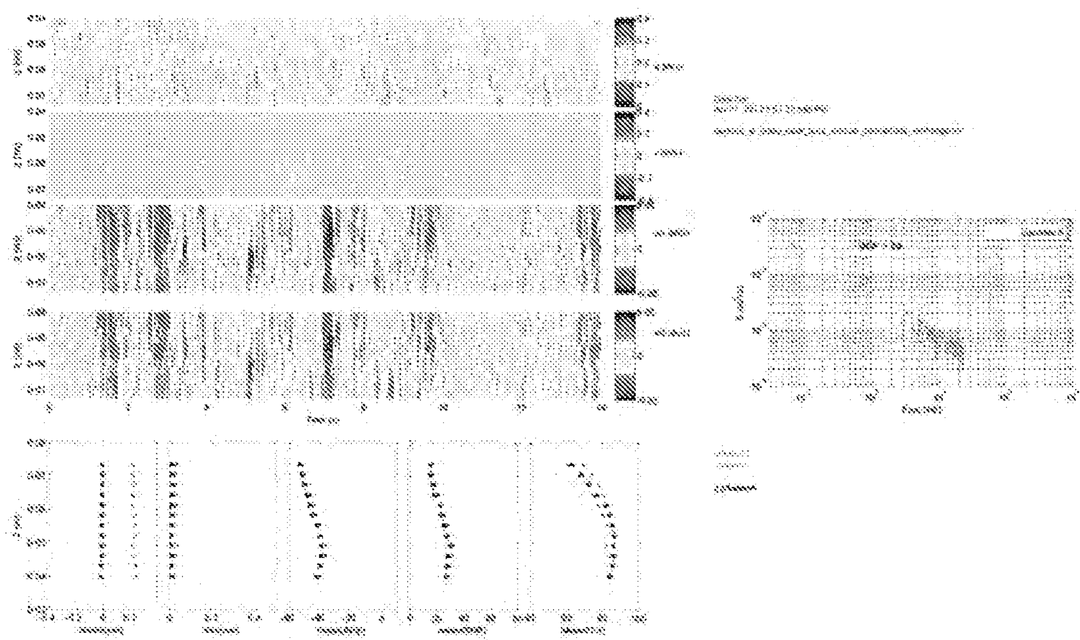


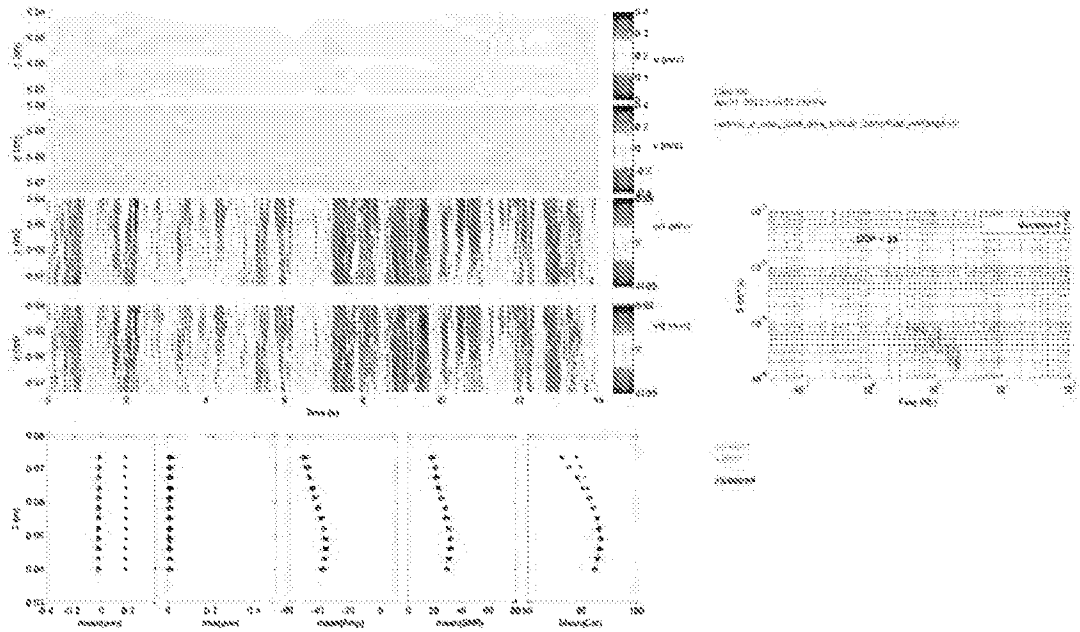


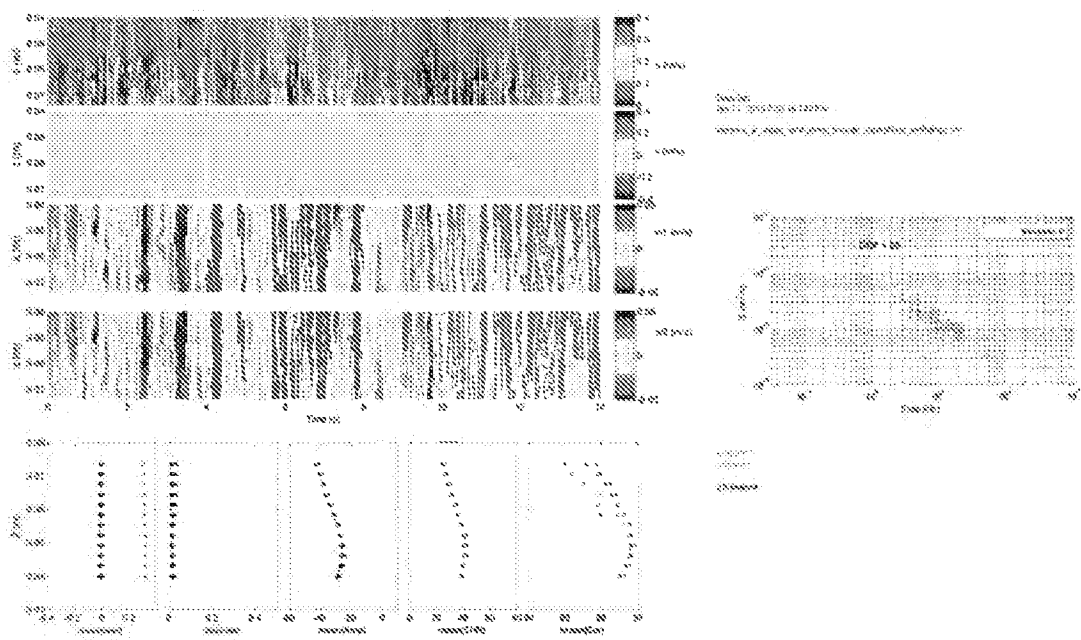


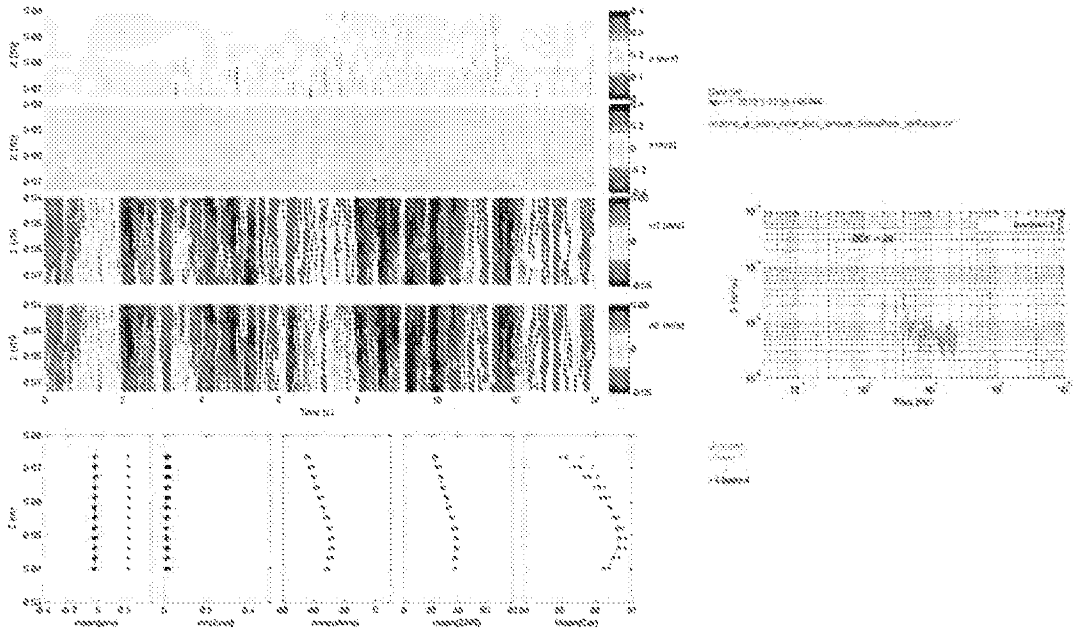


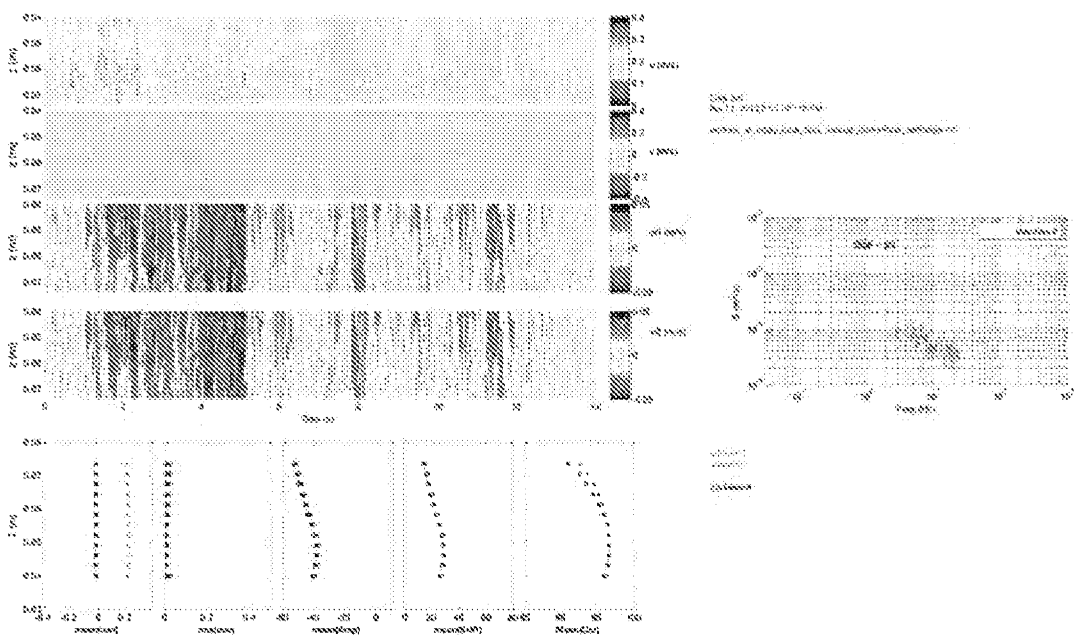


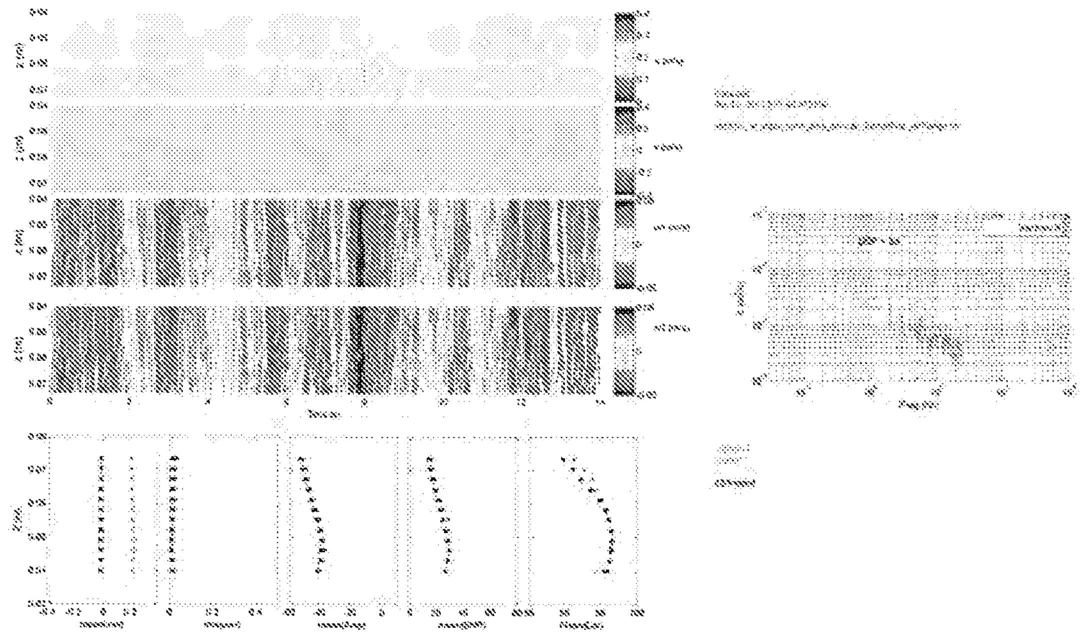


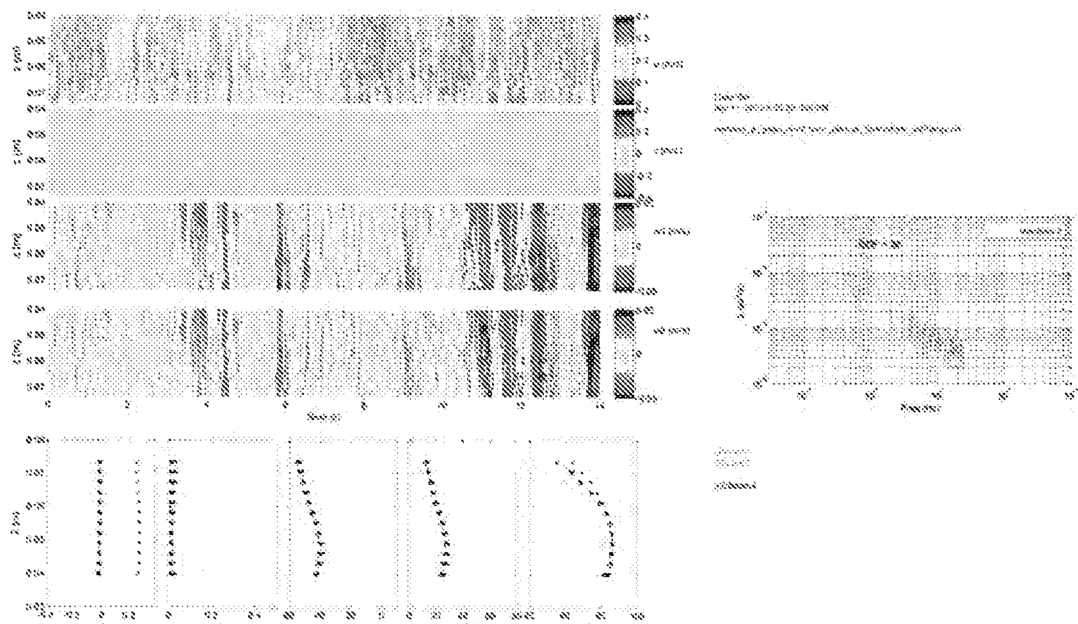


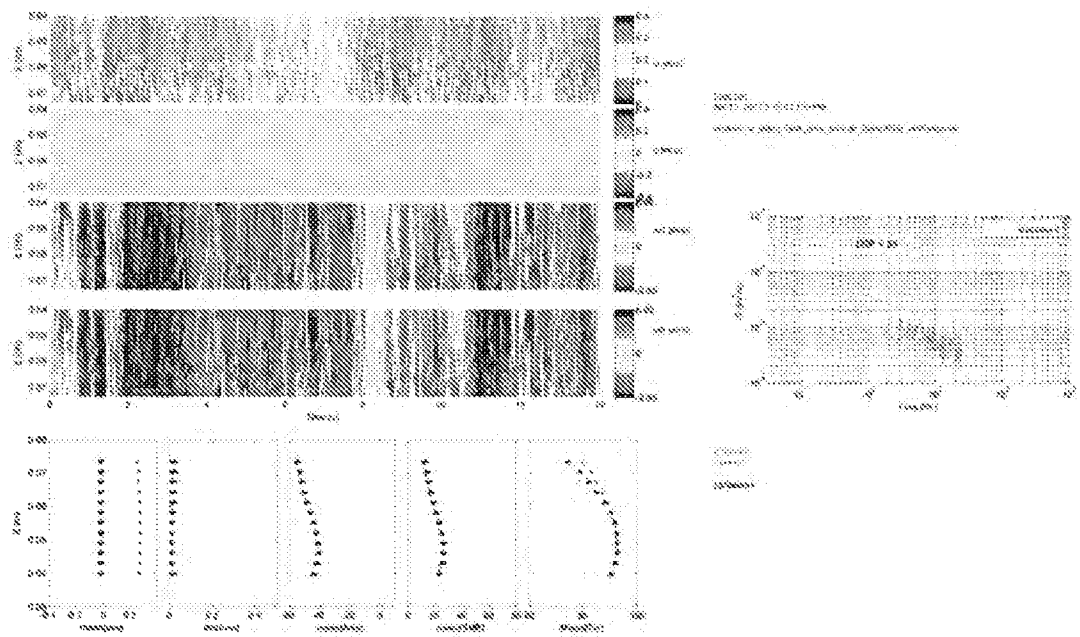


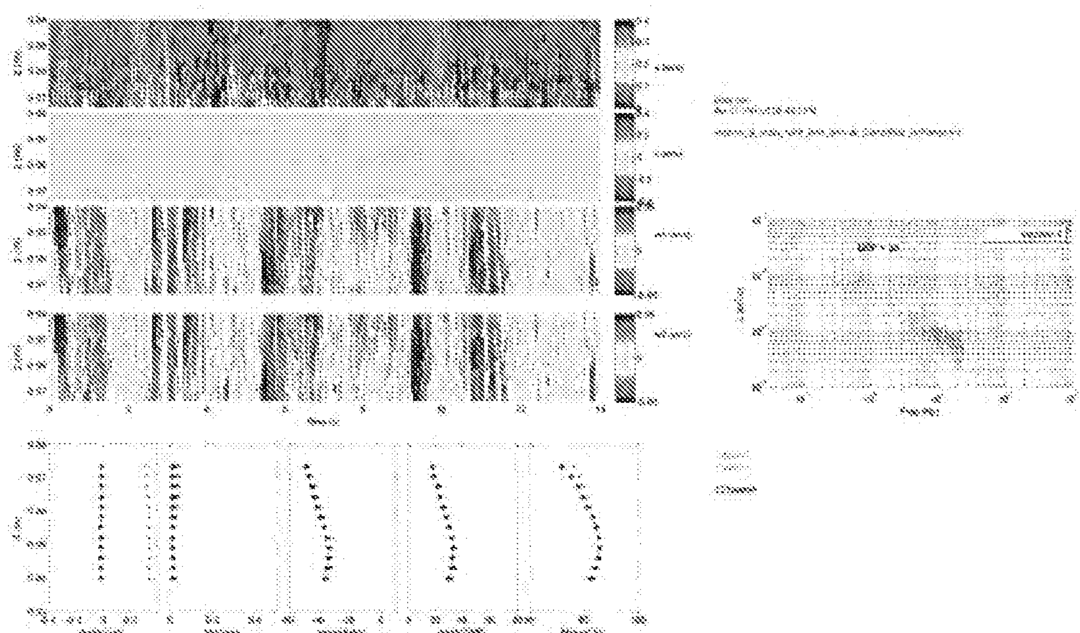


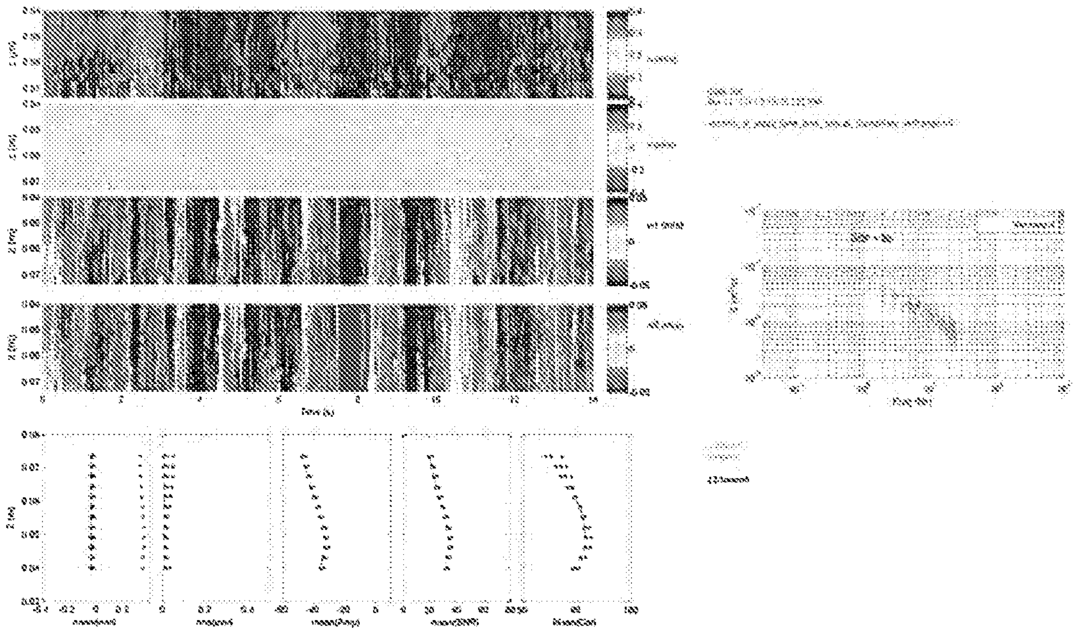


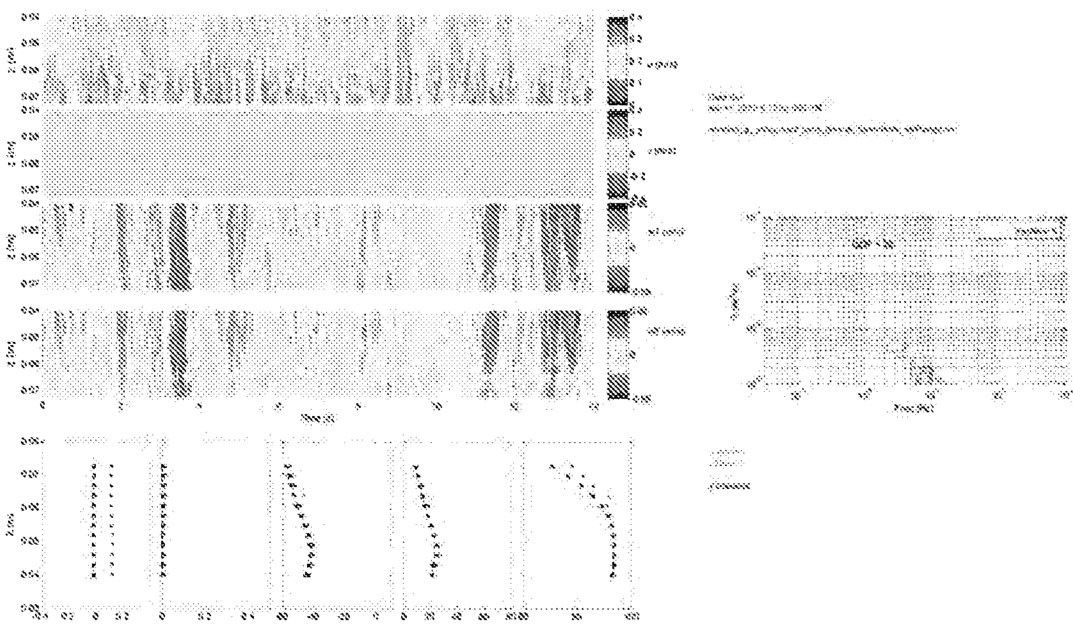


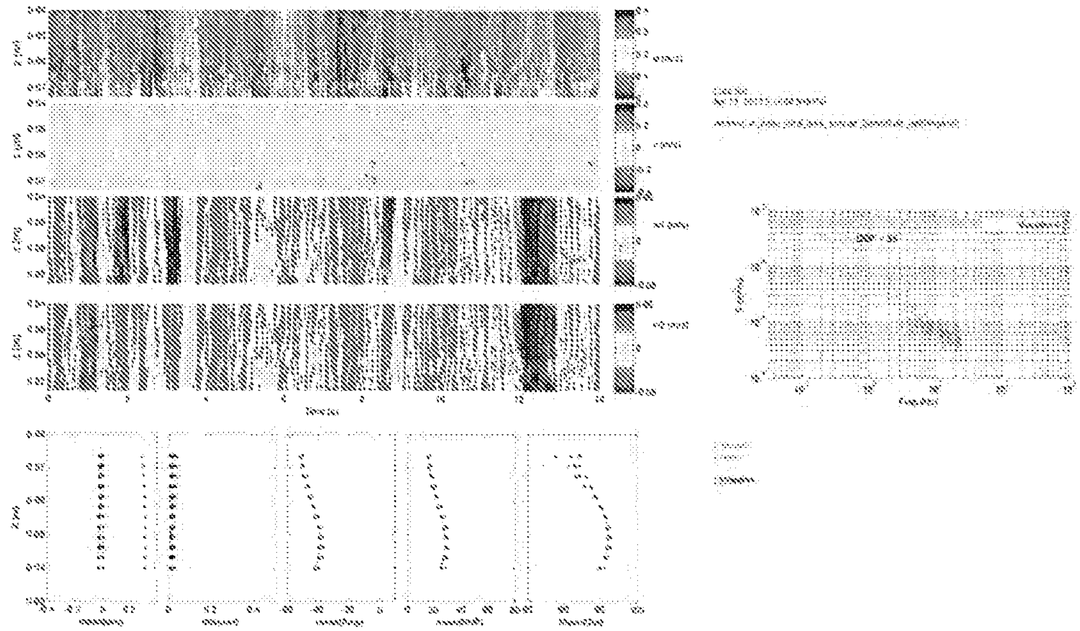


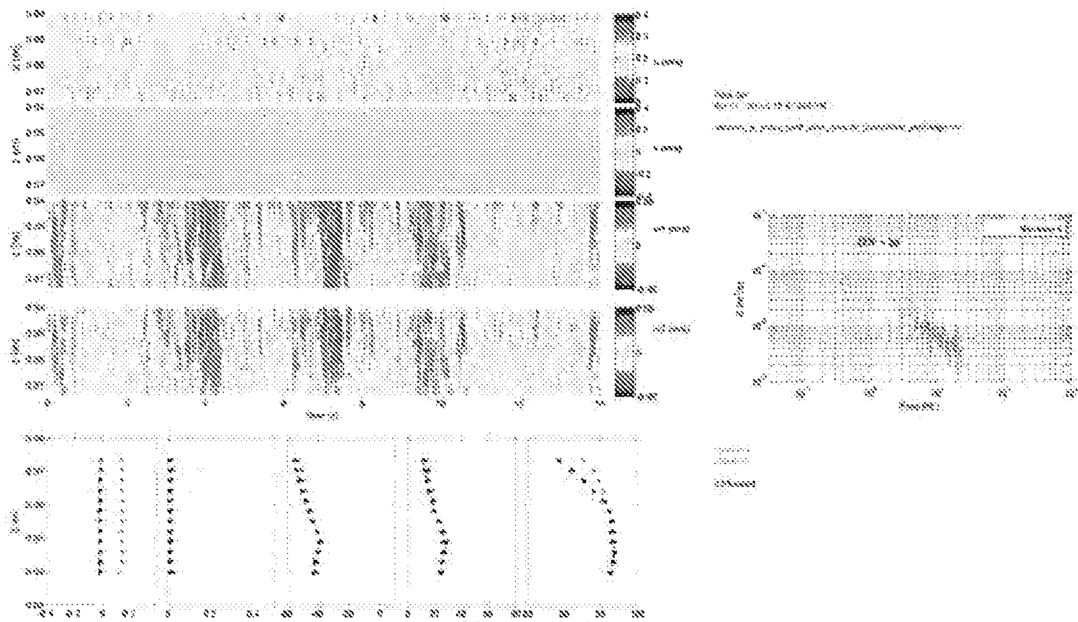


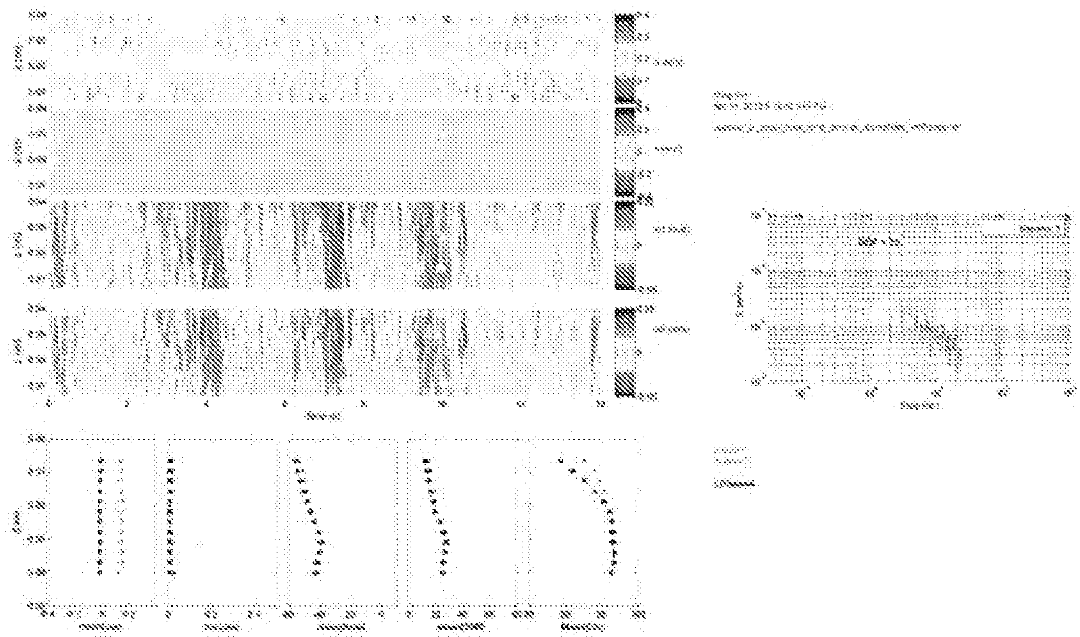


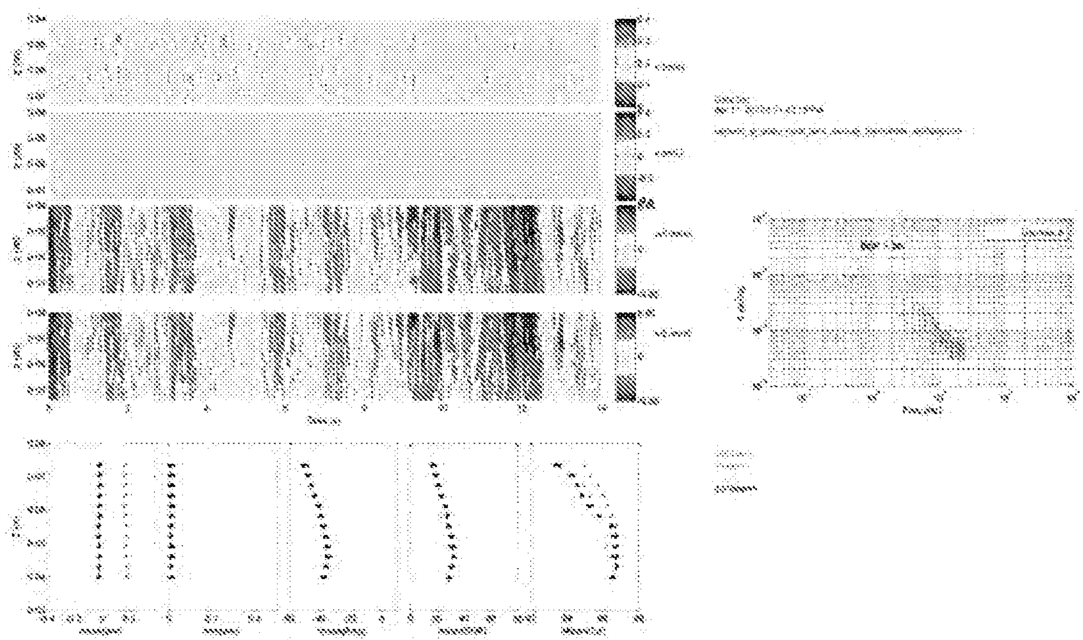


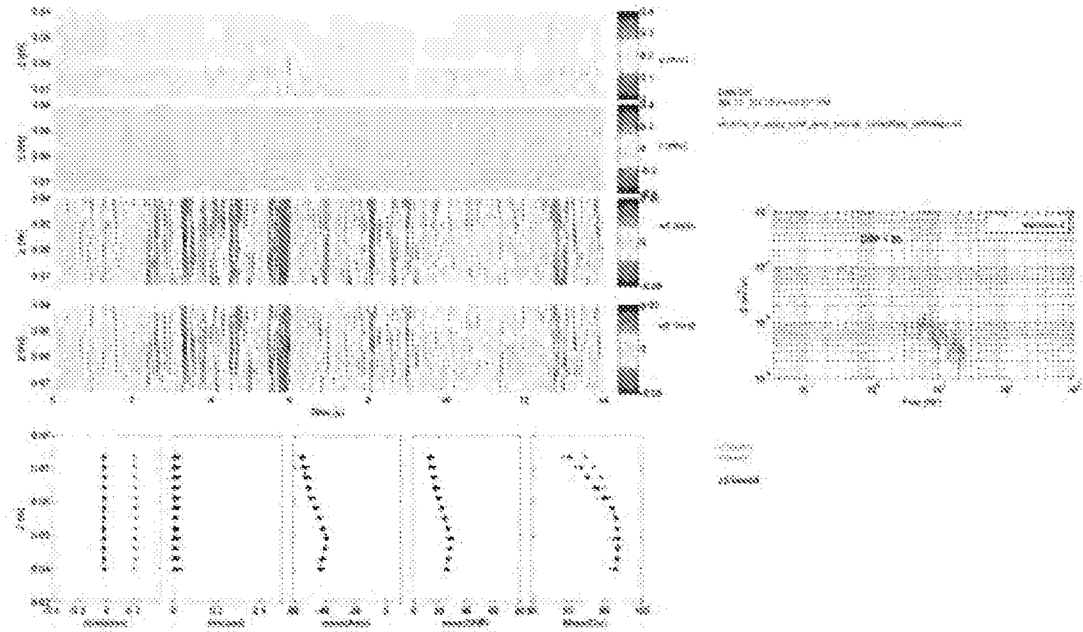


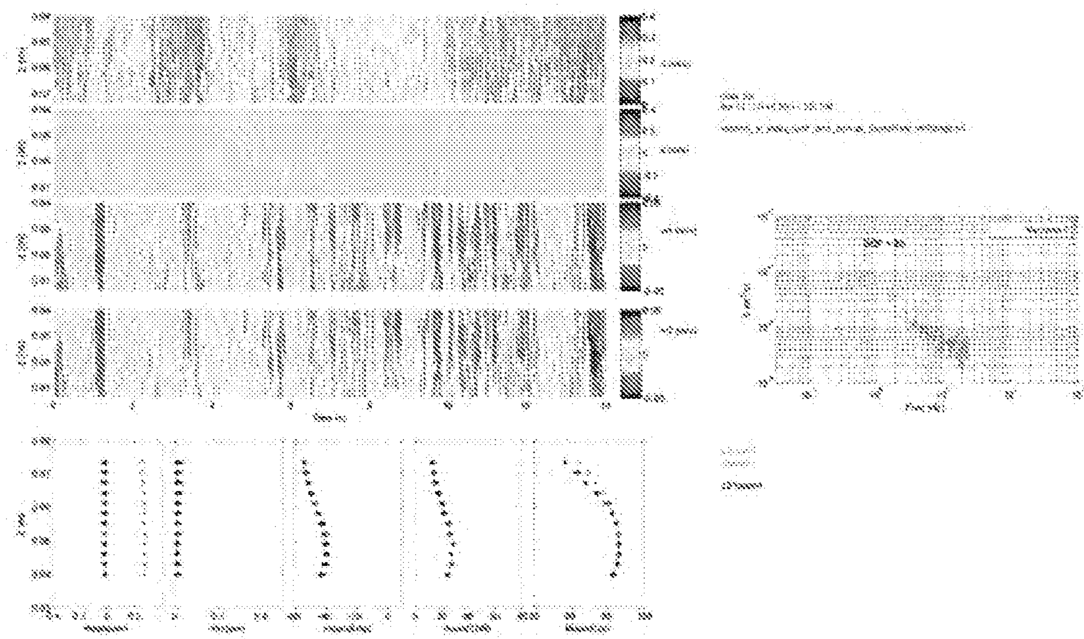


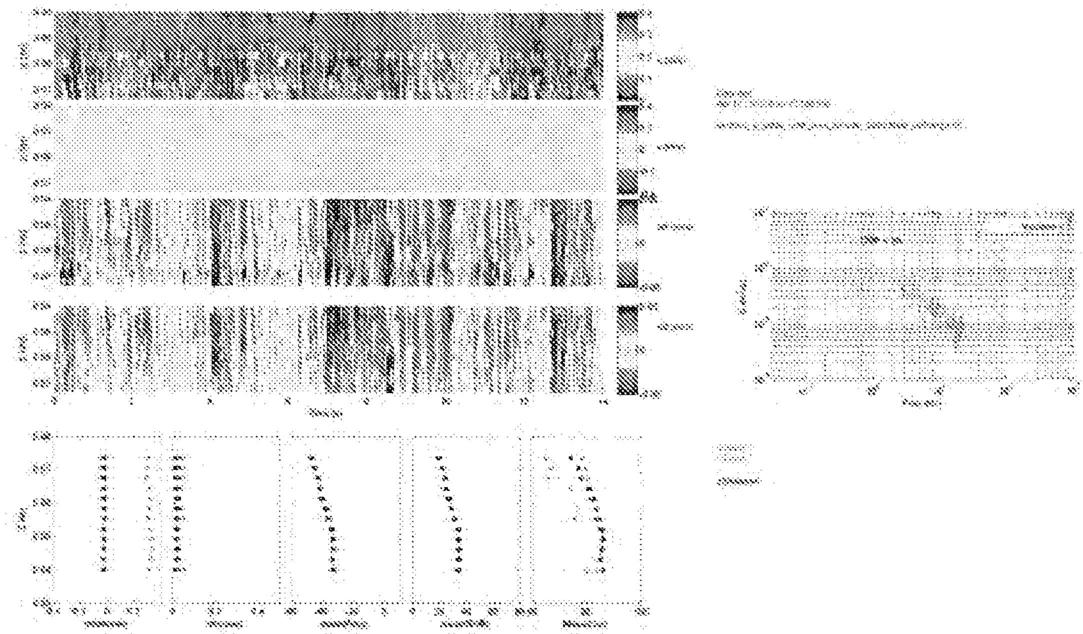


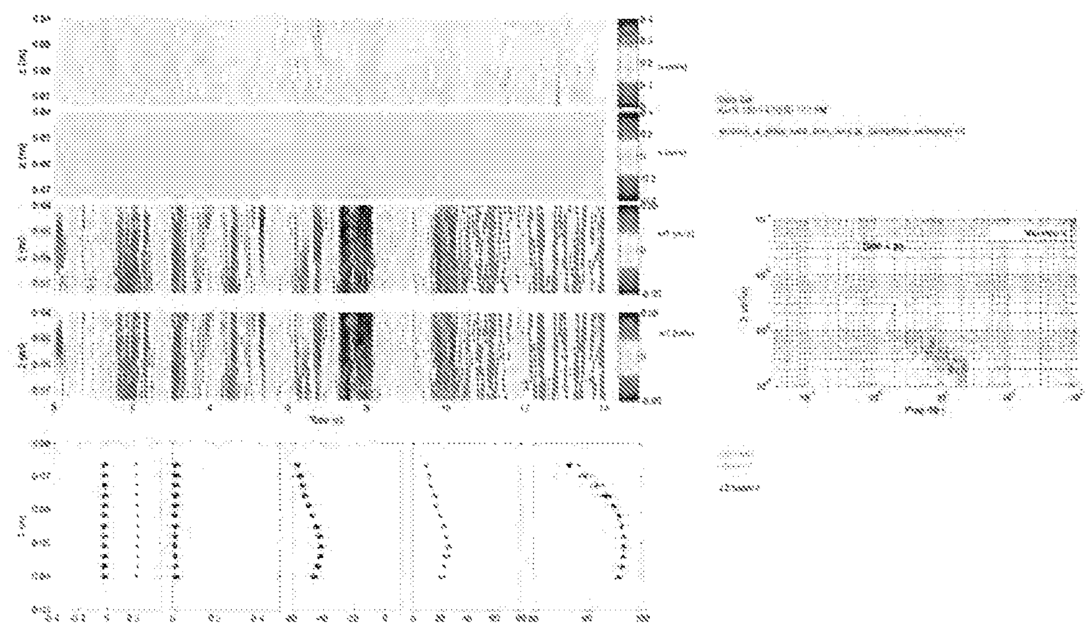












Appendix B

Recorded data using Microsoft Excel

Below are multiple tables showing velocity readings in the x y and two estimates of the z direction. These values were recorded by hand at the end of each 2 minute run. Although these numbers are only estimates, the root mean square of the recorded data is so minimal that these values can be labeled as the true estimates.

Location 1

Inside Position

Speed setting	Outside 1	Outside 2	Outside 3
X velocity (cm/s)	15.3	18.3	23.02
(+/-)	1.5	1.49	2.35
Y Velocity (cm/s)	-1.4	-1.6	-1.6
(+/-)	1	1.4	1.9
(-) Z1 velocity (cm/s)	1.6	2	2.14
(+/-)	0.65	0.9	1.15
(-) Z2 Velocity (cm/s)	1.5	1.8	2.17
(+/-)	0.6	0.9	1.16

Speed setting	Inside 1	Inside 2	Inside 3
X velocity (cm/s)	22.72	28.6	34.9
(+/-)	1.87	1.9	2.14
Y Velocity (cm/s)	-0.51	-1.1	-1
(+/-)	1.54	1.8	2.27
(-) Z1 velocity (cm/s)	2.13	3.35	3.36
(+/-)	0.7	0.7	1.3
(-) Z2 Velocity (cm/s)	2.18	2.9	3.39
(+/-)	0.7	0.7	1.2

Middle Postion

Speed Setting	Outside 1	Outside 2	Outside 3
X velocity (cm/s)	20.4	24.3	30.92
(+/-)	1.6	1.6	2.96
Y Velocity (cm/s)	0	-0.36	0.79
(+/-)	1	1.66	2.87
(-) Z1 velocity (cm/s)	1.2	2.06	1.81
(+/-)	1	0.87	1.65
(-) Z2 Velocity (cm/s)	1.2	2.05	1.75
(+/-)	1	0.91	1.71

Speed Setting	Inside 1	Inside 2	Inside 3
X velocity (cm/s)	2.35	28.5	36
(+/-)	1.5	2.3	2.3
Y Velocity (cm/s)	-0.65	-1.2	-1.6
(+/-)	1.8	2.2	2.5
(-) Z1 velocity (cm/s)	1.8	2.3	2.3
(+/-)	1	1	1.5
(-) Z2 Velocity (cm/s)	1.97	2.7	2.8
(+/-)	0.94	1	1.5

Outside Position

Speed setting	Outside 1	Outside 2	Outside 3
X velocity (cm/s)	24	30	38
(+/-)	1.5	2	2.8
Y Velocity (cm/s)	0	0	0
(+/-)	1.8	2.2	1.5
(-) Z1 velocity (cm/s)	2	2	3
(+/-)	1.2	1.2	1.6
(-) Z2 Velocity (cm/s)	2	2	4
(+/-)	1.2	1.2	1.6

Speed setting	Inside 1	Inside 2	Inside 3
X velocity (cm/s)	23	27	35
(+/-)	1.4	3	2.5
Y Velocity (cm/s)	0	-1	-2
(+/-)	1.8	2	3
(-) Z1 velocity (cm/s)	2	1.5	2.5
(+/-)	0.8	1.2	2
(-) Z2 Velocity (cm/s)	2	1.5	2.5
(+/-)	0.8	1.2	2

Location 2

Inside	data set 12-start		
Outside Motor			
Setting	1	2	3
x	12	14.63	17.83
σx	1	1.24	1.63
y	-1.43	-2.04	-2.33
σy	0.88	1.11	1.72
z	-1.67	-1.67	-1.89
σz	0.46	0.74	1.08
inside Motor			
Setting	1	2	3
x	22.2	27.3	30.43
σx	1.28	2.43	4.12
y	-2.63	-2.8	-3.22
σy	1.72	2	2.34
z	-0.78	-1.42	-1.78
σz	0.97	0.87	1.48

Middle	data set 6-start		
Outside Motor			
Setting	1	2	3
x	19.5	23.5	31.6
σx	1.6	2	2
y	0.4	0	0.2
σy	1.3	1.5	2
z	-0.92	-1.2	-1.22
σz	0.83	1	1.5
inside Motor			
Setting	1	2	3
x	21.8	27.78	33.5
σx	1.5	1.75	2.43
y	-0.88	-1.15	-1.37
σy	1.52	2.1	2.67
z	-1.38	-2	-2.12
σz	1.3	1	1.42

Outside	data set 14-start		
Outside Motor Setting	1	2	3
x	26.5	33.5	42.5
σx	2	2.5	3
y	0	0.86	-0.4
σy	1.5	2.4	2.96
z	1.5	-2	-2.85
σz	1	1.3	1.7

Inside Motor Setting	1	2	3
x	22	26.8	32.7
σx	1.6	2.3	3.5
y	-1.1	-1.5	-2.6
σy	2.13	2.5	3.2
z	-2.19	-1.4	-1.05
σz	1.29	1.5	1.8

Location 3

Outside

Speed Setting	Outside 1	Outside 2	Outside 3
X velocity (cm/s)	23	29	37
(+/-)	1.5	2	3
Y Velocity (cm/s)	0.1	0.6	1.7
(+/-)	1.2	2	2
(-) Z1 velocity (cm/s)	1.5	2	2.5
(+/-)	0.9	1.3	1.6
(-) Z2 Velocity (cm/s)	1.5	2	2.5
(+/-)	0.9	1.3	1.6

Speed Setting	Inside 1	Inside 2	Inside 3
X velocity (cm/s)	23	28	36
(+/-)	1.5	2	2.4
Y Velocity (cm/s)	0	0	0
(+/-)	1.6	2	4
(-) Z1 velocity (cm/s)	1.8	2.3	3
(+/-)	0.9	1	1.5
(-) Z2 Velocity (cm/s)	1.8	2.3	3
(+/-)	0.9	1	1.5

Appendix C

Matlab code

```
% Steve Collister Brett Coldman
% Senior Project
% Power Code
clc, clear, close all
%% variables
v=1.004*10^-6; % m^2/s @ 20 C
OD=3.353; % m tank size
ID=2.134; % m tank size
h=.30; % m tank height
b=.61; % m cross sectional base
U=(0:.01:.5)'; % m/s
p=1000; % kg/m^3
Ks=2.5*0.2*10^-3; % m
Di=.032;% 1 m pipe size
Do=.038;% 4 m pipe size

Ac=b*h;
Pw=2*h+b;
L=Ac/Pw;

Re=U*L/v;
figure, plot(U,Re);
title('Reynolds Number vs Velocity');
xlabel('Velocity (m/s)');
ylabel('Reynolds Number');

Aout=pi*OD*h;
Ain=pi*ID*h;
Abottom=pi*((OD/2)^2-(ID/2)^2);
Asurf=Aout+Ain+Abottom;
Acyl=24*pi+2*pi*4;
  HP from thrust
  thrust in lbf convert to N
  multiply by actual velocity
  convert W to HP

% everything commented out is directly related to the [illegible]

% f_min=0;
% f_max=1;
% Rey=40*Re; % make place for the Re, couldn't figure out how to
             % call the function without an error reading with the Re
             % being another function, so I took the highest value since
             % in Rey, change anything for a friction value

  f=fminbnd(@(f) [illegible],f_min,f_max);

  radius of curvature
```

```
dtheta=0:.01:.436;%pi;
DD=dtheta;
r=2.743; % middle radius in meters
Upipe=(4/pi)*U;

%  coefficient of friction
f=0.075./(log10(Re)-2).^2;

%  Power in Watts
%for ii=1:length(dtheta)
n=124;
% Tube array power compensation
%  1.5" ID pipes
P2=(p.*U.^3.*f./2)*(Asurf*ones(size(DD))+(n.*pi.*Di.*r.*DD)+(n.*pi.*Do.*r.*DD
)+Acyl*ones(size(DD)))+(p.*Ac.*U.^3)*ones(size(DD)); % start up
P3=(p.*U.^3.*f./2)*(Asurf*ones(size(DD))+(n.*pi.*Di.*r.*DD)+(n.*pi.*Do.*r.*DD
)+Acyl*ones(size(DD))); % flowing
%end

% Porous block power compensation
PP=(p.*Upipe.^3.*f./2)*(Asurf*ones(size(DD))+(240.*pi.*Di.*r.*DD)+Acyl*ones(s
ize(DD)))+(p.*Ac.*U.^3)*ones(size(DD));   % start up
PPP=(p.*Upipe.^3.*f./2)*(Asurf*ones(size(DD))+(240.*pi.*Di.*r.*DD)+Acyl*ones(
size(DD))); % flowing


%% Power in HP
%  Tube array power

%  1.5" pipes
HP2=(1/745.7)*P2;    % start up
HP3=(1/745.7)*P3;    % flowing


% porous block power
HPP=(1/745.7)*PP; % start up
HPPP=(1/745.7)*PPP; % flowing

figure, plot(U,HP2,U,HP3,U,HPP,U,HPPP);
title('Horsepower vs Velocity');
xlabel('Velocity (m/s)');
ylabel('Horsepower (HP)');
legend('Tube Array Initial Motor Thrust','Tube Array Motor Thrust for Uniform
Velocity'...
    ,'Porous Block Initial Motor Thrust','Porous Block Motor Thrust for
Uniform Velocity');


%imagesc([illegible]);

figure,
imagesc(DD,flipud(U),HP2)
colorbar
xlabel('flow straightener angle (Rad)');
```

```
ylabel('velocity (m/s)');
yLimits = get(gca,'YLim');  %# Get the y axis limits
yTicks = yLimits(2)-get(gca,'YTick');  %# Get the y axis tick values and
                                       %#   subtract them from the upper
limit
set(gca,'YTickLabel',num2str(yTicks.'));
%title('HP compensation for flow straightener length vs velocity');
title('HP compensation for 1.5" ID tube design length vs velocity');

t = colorbar('peer',gca);
set(get(t,'ylabel'),'String', 'Horsepower');

figure,
imagesc(DD,flipud(U),HPP)
colorbar
xlabel('flow straightener angle (Rad)');
ylabel('velocity (m/s)');
yLimits = get(gca,'YLim');  %# Get the y axis limits
yTicks = yLimits(2)-get(gca,'YTick');  %# Get the y axis tick values and
                                       %#   subtract them from the upper
limit
set(gca,'YTickLabel',num2str(yTicks.'));
%title('HP compensation for flow straightener length vs velocity');
title('HP compensation for porous block design length vs velocity');

t = colorbar('peer',gca);
set(get(t,'ylabel'),'String', 'Horsepower');




  [illegible]
% Senior Project
% Tube Code
clc, clear, close all
%  1.5" [illegible]
%% array for tube lengths
NEWw=1.5; % tube width (inches)
NEWir=42.758; % inner tube center radial distance (inches)
NEWor=65.258; % outer tube center radial distance (inches)

NEWR=NEWir:NEWw:NEWor;   % range of radii (inches)

NEWL=(15/360)*2*pi*NEWR; % individual tube length array (inches)

NEWLength=sum(NEWL);   % total tube length per layer (inches)

NEWfeet=NEWLength/12;   % total length converted to ft

NEWtube=NEWfeet*6;   % total tube length for all six layers

tube16=NEWL';

  %% new tube length
```

```
NEWIR=43.508;
NEWOR=64.508;

NEWR2=NEWIR:NEWw:NEWOR;

NEWL2=(15/360)*2*pi*NEWR2;

NEWLength2=sum(NEWL2);

NEWfeet2=NEWLength2/12;

NEWtube2=NEWfeet2*6;

tube15=NEWL2';

NEWtotal_tubing=NEWtube+NEWtube2;
```

```
%% Vectrino II QAQC sheet
% Created by Morgan Hargrove
% Modified May 31 2012, MEM

clear all; clc;

warnState = warning('off', 'MATLAB:gui:latexsup:BadTeXString');

%%These are all of the variable that you should change to run code
cr = 0.4; %This is the range of the x and y velocity in m/s
crz = 0.05; %This is the range of the w component of velocity in m/s
samp = .9; %sampling time in minutes
Start_time_vectrino_index = 4700; % make this something other than 1 if you
do not want to see the beginning of the timeseries
endindex = samp*60*100;
SamplingFreq = 100; %Hz
distBotVec = 0.068; %Distance in meters Vectrino center beam is from bed
%If want to save figure to file need to uncomment last two lines of code
%and redirect to desired folder

%%Change this to the path where the data is stored
%cd('vcdo-_92')


vectrino_fstruct = dir('VectrinoData*.mat');

file2loadVectrino = 72;
fname=vectrino_fstruct(file2loadVectrino).name;
fname=fname(1:(length(fname)-4));
outputname = ['qaqc_' fname '.pdf']; %Change this based on what you want the
output file to be called
```

```
importfile_mew(vectrino_fstruct(file2loadVectrino).name);

[pathstr, fnameVectrino, ext] = fileparts(Config(1).fileName);



time = Data(1).Profiles_TimeStamp; %Define Time

velx = Data(1).Profiles_VelX;
vely = Data(1).Profiles_VelY;
velz1 = Data(1).Profiles_VelZ1;
velz2 = Data(1).Profiles_VelZ2;
Bins = Data(1).Profiles_Range;

%% Create Figure axis locations and sizes
figure(1);
clf
orient landscape;
velxh = axes('position',[.1 .84 .5 .13]); %[left bot width height]
box on;
%xlim([0 samp*60]);
ylim([min(Bins) max(Bins)]);
set(gca,'XTickLabel',[]);
ylabel('z (m)','FontSize',12);
hold on
velyh = axes('position',[.1 .70 .5 .13]);
box on;
%xlim([0 samp*60]);
ylim([min(Bins) max(Bins)]);
set(gca,'XTickLabel',[]);
ylabel('z (m)','FontSize',12);
hold on
velz1h = axes('position',[.1 .56 .5 .13]);
box on;
xlim([0 samp*60]);
ylim([min(Bins) max(Bins)]);
%ylim([-.3 .7]);
set(gca,'XTickLabel',[]);
ylabel('z (m)','FontSize',12);
hold on
velz2h = axes('position',[.1 .4 .5 .13]);
box on;
%xlim([0 samp*60]);
ylim([min(Bins) max(Bins)]);
%set(gca,'XTickLabel',[]);
xlabel('Time (s)');
ylabel('z (m)','FontSize',12);
hold on
% saph = axes('position',[.1 .44 .5 .08]);
% box on;
% xlim([0 1800]);
% xlabel('Time (sec)','FontSize',12);
% ylabel('z (m)','FontSize',12);
```

```
%Create Statistic Figure axis locations and Sizes
hold on
meanvelh = axes('position',[.1 .085 .09 .25]);
xlim([-.4 .4]);
box on;
%axis([-.5 .5 .18 .23]);
xlabel('mean(uvw)','FontSize',10);
ylabel('Z (m)','FontSize',10);
hold on
stdvelh = axes('position',[.2 .085 .09 .25]);
set(gca,'YTickLabel',[]);
xlim([0 .5]);
box on;
%axis([-.3 .3 .18 .23]);
xlabel('rms(uvw)','FontSize',10);
hold on
meanamph = axes('position',[.3 .085 .09 .25]);
set(gca,'YTickLabel',[]);
xlim([-60 10]);
box on;
%axis([-80 0 .18 .23]);
xlabel('mean(Amp)','FontSize',10);
hold on
meansnrh = axes('position',[.4 .085 .09 .25]);
set(gca,'YTickLabel',[]);
xlim([0 80]);
box on;
%axis([0 50 .18 .23]);
xlabel('mean(SNR)','FontSize',10);
hold on
meancorh = axes('position',[.5 .085 .09 .25]);
set(gca,'YTickLabel',[]);
%xlim([20 100]);
box on;
%axis([50 100 .18 .23]);
xlabel('Mean(Cor)','FontSize',10);


%Spectrum Axis
hold on,
spech = axes('position',[.7 .42 .25 .25]);
box on;



%% BEGIN PLOTTING

bin=Config(1).nCells; %number of bins

%Plot velx
%Match time
dtvec = datevec(Config(1).date);
dateyrday=
date_to_yearday(dtvec(1,1),dtvec(1,2),dtvec(1,3),dtvec(1,4),dtvec(1,5));
%yeartime
```

```
distz = (Data(1).Profiles_Range);
set(gcf,'CurrentAxes',velxh);
set(gca,'YDir','reverse');


plottime(:,1) = time(Start_time_vectrino_index:endindex,1)-
time(Start_time_vectrino_index,1);



 dpp =1:length(velx);



pcolor(transpose(double(plottime(1:end,1))),transpose(double(Bins(1,:))),tran
spose(double(velx(Start_time_vectrino_index:endindex,:))));
shading flat;
colorbar;
caxis([0 cr]);
xlim([min(plottime) max(plottime)]);


%vel y
set(gcf,'CurrentAxes',velyh);
set(gca,'YDir','reverse');

plottime(:,1) = time(Start_time_vectrino_index:endindex,1)-
time(Start_time_vectrino_index,1);


pcolor(transpose(double(plottime(1:end,1))),transpose(double(Bins(1,:))),tran
spose(double(vely(Start_time_vectrino_index:endindex,:))));
shading flat;
%ylim([distz(1,end) distz(1,1)]);
colorbar;
caxis([-cr cr]);
xlim([min(plottime) max(plottime)]);

%vel z
set(gcf,'CurrentAxes',velz1h);
set(gca,'YDir','reverse');
plottime(:,1) = time(Start_time_vectrino_index:endindex,1)-
time(Start_time_vectrino_index,1);


pcolor(transpose(double(plottime(1:end,1))),transpose(double(Bins(1,:))),tran
spose(double(velz1(Start_time_vectrino_index:endindex,:))));
shading flat;

colorbar;
caxis([-crz crz]);
xlim([min(plottime) max(plottime)]);
```

```
%% z
set(gcf,'CurrentAxes',velz2h);
set(gca,'YDir','reverse');

plottime(:,1) = time(Start_time_vectrino_index:endindex,1)-
time(Start_time_vectrino_index,1);


pcolor(transpose(double(plottime(1:end,1))),transpose(double(Bins(1,:))),tran
spose(double(velz2(Start_time_vectrino_index:endindex,:))));
shading flat;

colorbar;
caxis([-crz crz]);
xlim([min(plottime) max(plottime)]);

% get amplitude and snr data
ampBeam1 = Data(1).Profiles_AmpBeam1;

ampBeam2 = Data(1).Profiles_AmpBeam2;

ampBeam3 = Data(1).Profiles_AmpBeam3;

ampBeam4 = Data(1).Profiles_AmpBeam4;

snrBeam1 = Data(1).Profiles_SNRBeam1;

snrBeam2 = Data(1).Profiles_SNRBeam2;

snrBeam3 = Data(1).Profiles_SNRBeam3;

snrBeam4 = Data(1).Profiles_SNRBeam4;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% for mean velocity
dmm=1:bin;
set(gcf,'CurrentAxes',meanvelh);
col=hsv(25);
velXMean = mean(velx);

hold on;
plot(velXMean(1,dmm),distz(1,dmm),'marker','.','color','r');



set(gcf,'CurrentAxes',meanvelh);
col=hsv(25);
velYMean = mean(vely);
hold on;
plot(velYMean(1,dmm),distz(1,dmm),'marker','.','color','r');
```

```
set(gcf,'CurrentAxes',meanvelh);
col=hsv(25);
velZ1Mean = mean(velz1);
hold on;
plot(velZ1Mean(1,dmm),distz(1,dmm),'marker','.','color','g');


set(gcf,'CurrentAxes',meanvelh);
col=hsv(25);
velZ2Mean = mean(velz2);
hold on;
plot(velZ2Mean(1,dmm),distz(1,dmm),'marker','.','color','k');


%Plot RMS velocity
set(gcf,'CurrentAxes',stdvelh);
col=hsv(25);
rmsXvel = sqrt(mean(velx.^2));
hold on;
 lot(rmsXvel(1,dmm),distz(1,dmm),'marker','.','color','b');
plot(std(velx),distz(1,dmm),'marker','.','color','b');


set(gcf,'CurrentAxes',stdvelh);
col=hsv(25);
rmsYvel = sqrt(mean(vely.^2));
hold on;
 lot(rmsYvel(1,dmm),distz(1,dmm),'marker','.','color','r');
plot(std(vely),distz(1,dmm),'marker','.','color','r');


set(gcf,'CurrentAxes',stdvelh);
col=hsv(25);
rmsZ1vel = sqrt(mean(velz1.^2));
hold on;
%plot(rmsZ1vel(1,dmm),distz(1,dmm),'marker','.','color','g');
plot(std(velz1),distz(1,dmm),'marker','.','color','g');


set(gcf,'CurrentAxes',stdvelh);
col=hsv(25);
rmsZ2vel = sqrt(mean(velz2.^2));
hold on;
%plot(rmsZ2vel(1,dmm),distz(1,dmm),'marker','.','color','k');
plot(std(velz2),distz(1,dmm),'marker','.','color','k');


  %  mean amp
set(gcf,'CurrentAxes',meanamph);
col=hsv(25);
ampBeam1Mean = mean(ampBeam1);
hold on;
plot(ampBeam1Mean(1,dmm),distz(1,dmm),'marker','.','color','b');
```

```
set(gcf,'CurrentAxes',meanamph);
col=hsv(25);
ampBeam2Mean = mean(ampBeam2);
hold on;
plot(ampBeam2Mean(1,dmm),distz(1,dmm),'marker','.','color','c');


set(gcf,'CurrentAxes',meanamph);
col=hsv(25);
ampBeam3Mean = mean(ampBeam3);
hold on;
plot(ampBeam3Mean(1,dmm),distz(1,dmm),'marker','.','color','g');


set(gcf,'CurrentAxes',meanamph);
col=hsv(25);
ampBeam4Mean = mean(ampBeam4);
hold on;
plot(ampBeam4Mean(1,dmm),distz(1,dmm),'marker','.','color','k');



%Plot mean SNR
set(gcf,'CurrentAxes',meansnrh);
col=hsv(25);
snrBeam1Mean = mean(snrBeam1);
hold on;
plot(snrBeam1Mean(1,dmm),distz(1,dmm),'marker','.','color','b');


set(gcf,'CurrentAxes',meansnrh);
col=hsv(25);
snrBeam2Mean = mean(snrBeam2);
hold on;
plot(snrBeam2Mean(1,dmm),distz(1,dmm),'marker','.','color','r');


set(gcf,'CurrentAxes',meansnrh);
col=hsv(25);
snrBeam3Mean = mean(snrBeam3);
hold on;
plot(snrBeam3Mean(1,dmm),distz(1,dmm),'marker','>','color','y');


set(gcf,'CurrentAxes',meansnrh);
col=hsv(25);
snrBeam4Mean = mean(snrBeam4);
hold on;
plot(snrBeam4Mean(1,dmm),distz(1,dmm),'marker','<','color','k');


%Plot mean correlation
corBeam1 = Data(1).Profiles_CorBeam1;
```

```
corBeam2 = Data(1).Profiles_CorBeam2;
corBeam3 = Data(1).Profiles_CorBeam3;
corBeam4 = Data(1).Profiles_CorBeam4;

set(gcf,'CurrentAxes',meancorh);
col=hsv(25);
corBeam1Mean = mean(corBeam1);
hold on;
plot(corBeam1Mean(1,dmm),distz(1,dmm),'marker','.','color','b');


set(gcf,'CurrentAxes',meancorh);
col=hsv(25);
corBeam2Mean = mean(corBeam2);
hold on;
plot(corBeam2Mean(1,dmm),distz(1,dmm),'marker','.','color','r');


set(gcf,'CurrentAxes',meancorh);
col=hsv(25);
corBeam3Mean = mean(corBeam3);
hold on;
plot(corBeam3Mean(1,dmm),distz(1,dmm),'marker','.','color','g');


set(gcf,'CurrentAxes',meancorh);
col=hsv(25);
corBeam4Mean = mean(corBeam4);
hold on;
plot(corBeam4Mean(1,dmm),distz(1,dmm),'marker','.','color','k');

    [illegible]

frequency = Config(1).sampleRate;

%Spectrum Vectrino
axes(spech)
col=hsv(25);
[SbandVectrino, freqBandVectrino, DOFVectrino] =
spectrumtest1_diane(velx(:,5),10,1,1/frequency);
loglog(freqBandVectrino, SbandVectrino,'color','red');
hold on;
legend('Vectrino II','Vector');
grid on;
grid on;
ylabel('S (m^2/s)','FontSize',10);
xlabel('Freq (Hz)','FontSize',10);
str3 = ['DOF = ' num2str(DOFVectrino)];
annotation(figure(1),'textbox',[.77 .58 .28 .0625],'String',{str3},
'FitBoxToText','on','FontSize',10,'LineStyle','none');
%confidence intervals 95percent for 20 DOF
chisquarelow2=(9.59);
chisquarehigh2=(34.17);
lowCI3 = DOFVectrino*(10^-2)/(chisquarelow2);
highCI3 = DOFVectrino*(10^-2)/(chisquarehigh2);
```

```
line([5 5], [lowCI3 highCI3],'[illegible]','k');
hold on;
plot(5,10^-2,'.k');
ylim([10^-6 10^-3]);
xlim([10^-1.5 10^3]);

[illegible]

[illegible]
[illegible]
[illegible]
for [illegible]
%     [illegible] = mean(velz(tt:tt+100,drr));
%     tt = tt +100;
% end
%
% % find free stream
% dtt = length(blz);
% freestream(dtt,1) = mean(blz(dtt,1:12));
%
% for tt = 1:length(blz)
% delta99(tt,1) = closest(freestream(tt,1),transpose(blz(tt,:)));
% end
%
% figure;
% for kk = 1:100
% plot(kk/25+blz(kk,:),nisty);
% hold on
% end
% xlim(1:5);

%% Annotations
%set(gcf,'currentAxes',meanvelh);

str1 = [fnameVectrino(26:end-20)];
str2 = ['vectrino_yz_yrday_run#_bin#_binsize_SampRate_velRange.ntr'];
%set(gcf,'CurrentAxes',velh);
%text(-40,1.5,str,'FontSize',8,'Interpreter','none');
%annotation(figure(1), 'textbox', [.02 .93 .28 .0625],'String',[str1
str2],'FitBoxToText','on','FontSize',10,'LineStyle','none','Interpreter','non
e');

char1 = ['Data Set:'];
char2 = [Config(1).date];

text(120,.2,char,'FontSize',10)
% annotation(figure(1), 'textbox', [.53 .1 .28 .0625],'String',[char5 char7
char6 char7],'FitBoxToText','on','FontSize',9,'LineStyle','none');

annotation(figure(1), 'textbox', [.65 .8 .28 .0625],'string',[char1 char2
str1 str2
],'FitBoxToText','on','FontSize',9,'LineStyle','none','Interpreter','none');

annotation(figure(1), 'textbox', [.6 .85 .28 .0625],'String',['u
(m/s)'],'FitBoxToText','on','FontSize',10,'LineStyle','none');
```

```
annotation(figure(1), 'textbox', [.6 .72 .28 .0625],'String',{'v (m/s)'},'FitBoxToText','on','FontSize',10,'LineStyle','none');

annotation(figure(1), 'textbox', [.6 .6 .28 .0625],'String',{'v1 (m/s)' },'FitBoxToText','on','FontSize',10,'LineStyle','none');

annotation(figure(1), 'textbox', [.6 .48 .28 .0625],'String',{'v2 (m/s)'},'FitBoxToText','on','FontSize',10,'LineStyle','none');

%annotation(figure(1), 'textbox', [.55 .45 .28 .0625],'String','log Intensity','FitBoxToText','on','FontSize',10,'LineStyle','none');

annotation(figure(1), 'textbox', [.65 .27 .28 .0625],'String',{'\color{blue}u/beam1' '\color{red}v/beam2' '\color{green}z1/beam3' '\color{black}z2/beam4'},'FitBoxToText','on','FontSize',10,'LineStyle','none' );

%text(-.15,-2.5,['{\color{blue}u/beam1 \color{red}v/beam2 \color{green}z1/beam3 \color{black}z2/beam4}']);

% cd('/Users/meaganwengrove/Dropbox/meagan/OregonData_Vectrino/VectrinoII_Flat8ed');



 print(figure(1),'-dpdf',outputname)


% Velocity vs translational position

close all;
clear all;
clc;

x=[5.5 10.25 17.125];
v1=[12 19.5 26.5];
v2=[14.63 25.5 33.5];
v3=[17.83 31.6 42.5];


A=plot(x,v1,x,v2,x,v3)
title('Velocity vs translational position');
xlabel('Flume translational position from the outside flume wall (in)')
% set(gca,'xticklabel',{'Outside','Middle','Inside'});
ylabel('X velocity (cm/s)');
axis([0 18 0 45])
legend([A],'Speed setting 1','Speed setting 2','Speed setting 3')
```