higher than that of the non-perturbed case, which indicates that the perturbation introduced by the cylinder array is well sustained and organized throughout the measurement fields; that is to say, the dominant wake structure is most stabilized in this case.

Another interesting observation is that the distribution of the scales retains a shape similar to the non-perturbed case throughout the streamwise domain, which might suggest that the 0.6δ spacing perturbation has only a minor disruption of the flow structure. This makes sense as the 0.6δ mode is dominant in the non-perturbed flow of this study so perturbing this mode would be expectedly more efficient. Also noticeable is that the 1.2δ mode appears somewhat higher than the non-perturbed case. This is expected to be the result from instances where two cylinder wakes move toward opposite spanwise directions where the spacing between the wakes increases to 1.2δ. Further discussion on this point will be provided using the flying data.

Figure 3.18 gives the streamwise development of these modes. Note that the dominant scales are counted in the range of ±0.05δ so at given location the average probability of one specific mode is smaller than that shown in Figure 3.17. It is clear that the 0.2δ mode is not important in this case. The 0.6δ mode starts off with a high percentage of $\sim 90\%$ and comes to a local minimum at $x/\delta \sim 1$, corresponding to the location just before the presence of strong spanwise movement. Then it approaches a steady state at $x/\delta \sim 3$ and remains at the same level until the far field.

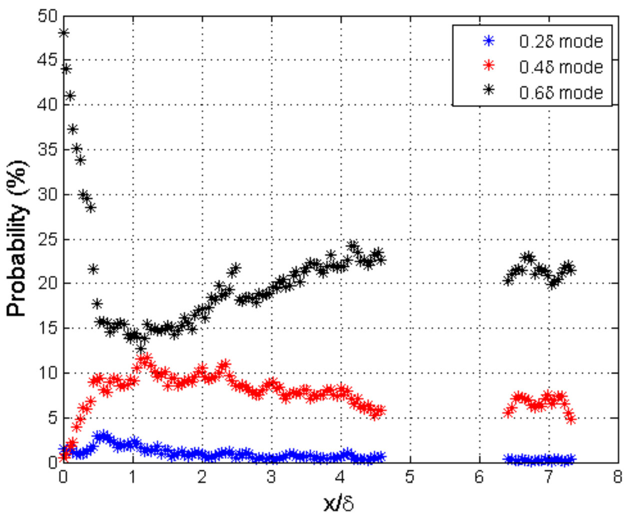

Figure 3. 18 Streamwise development of different spanwise modes for 0.6δ spacing case.

Different from the previous two cases, for 0.4δ and 0.6δ mode, no significant difference between their percentages at $x/\delta \sim 4.5$ and $x/\delta \sim 6.5$ is observed here, indicating that the flow structure is stable throughout these locations.

In Figure 3.19, the characteristic mode is defined as the same mode as the perturbation scale, e.g. 0.2δ mode for the 0.2δ spacing case. All data are normalized by the mean value of the corresponding percentage in the non-perturbed case as shown in Figure 3.11 so that 1 means the percentage of the mode is the same as that in the non-perturbed flow.

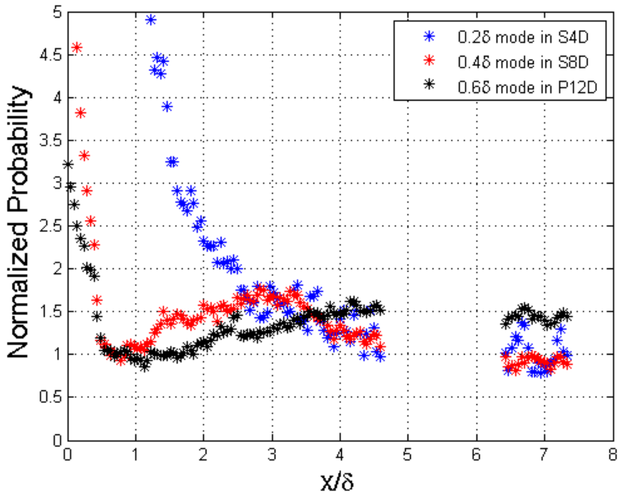

Figure 3. 19 Streamwise development of the characteristic modes.

It is obvious that in the far field, the normalized probability of 0.2δ and 0.4δ modes reverts to 1, suggesting that the importance of these modes is nominally the same as that in the non-perturbed case. However, for the 0.6δ case, the 0.6δ mode dominates about 1.5 times more often than the non-perturbed case, suggesting that the downstream LMRs remain coherent at the perturbation scale up to the far field at $x/\delta \sim 7$ downstream. This leads to the conclusion that by increasing the spanwise spacing of the cylinder array.

The detailed mechanism of the stability issue is not clear as of yet, but efforts will be made to answer that question by looking at the flow structures using instantaneous data fields in the next chapter.