# Techniques for the processing and analysis of image velocimetry data

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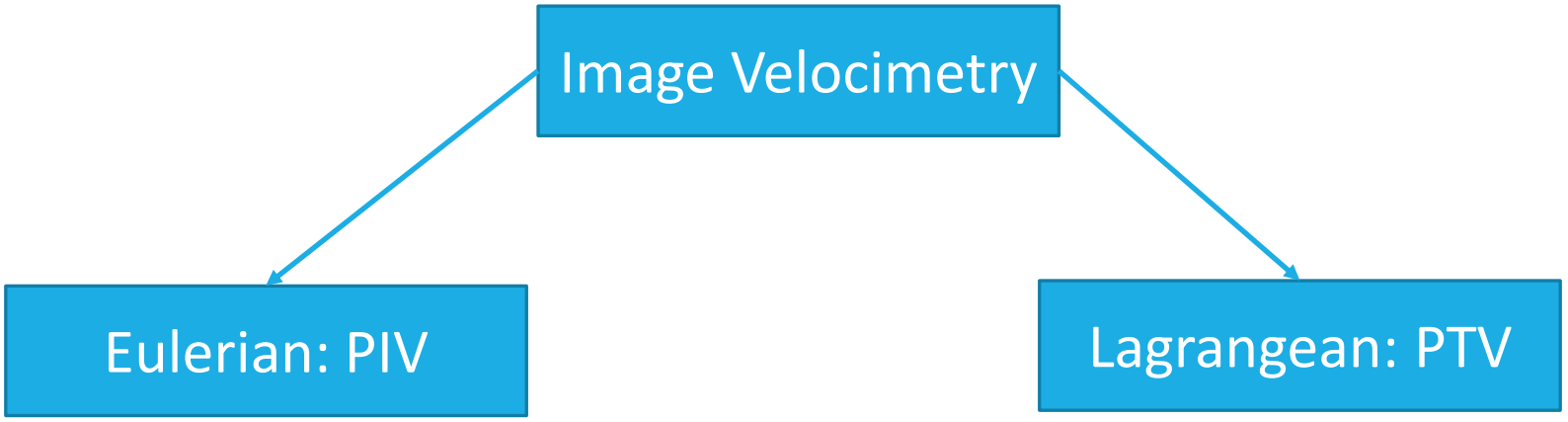
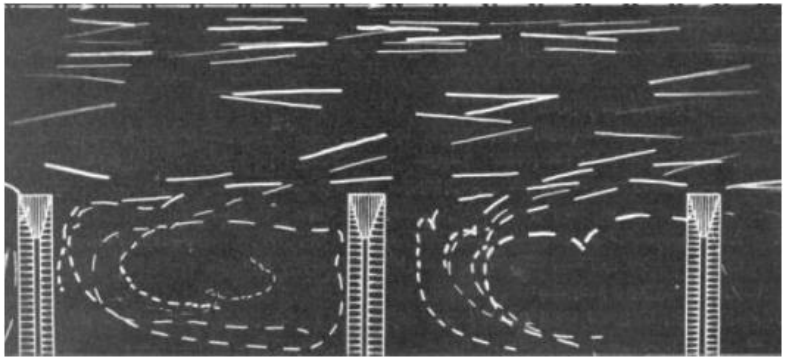
# Classical Image Velocimetry techniques




Theodor Rehbock, Karlsruhe, 1926

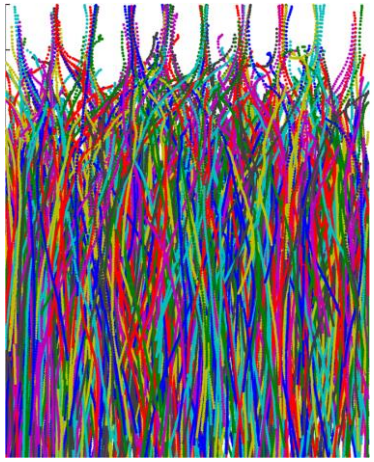


# Classical Image Velocimetry techniques: PTV

PTV algorithm, "ICCRM Method" is currently the most accurate available:

**Table 5** PTV results with known/unknown particle location and comparison to previous work of VSJ 301 image

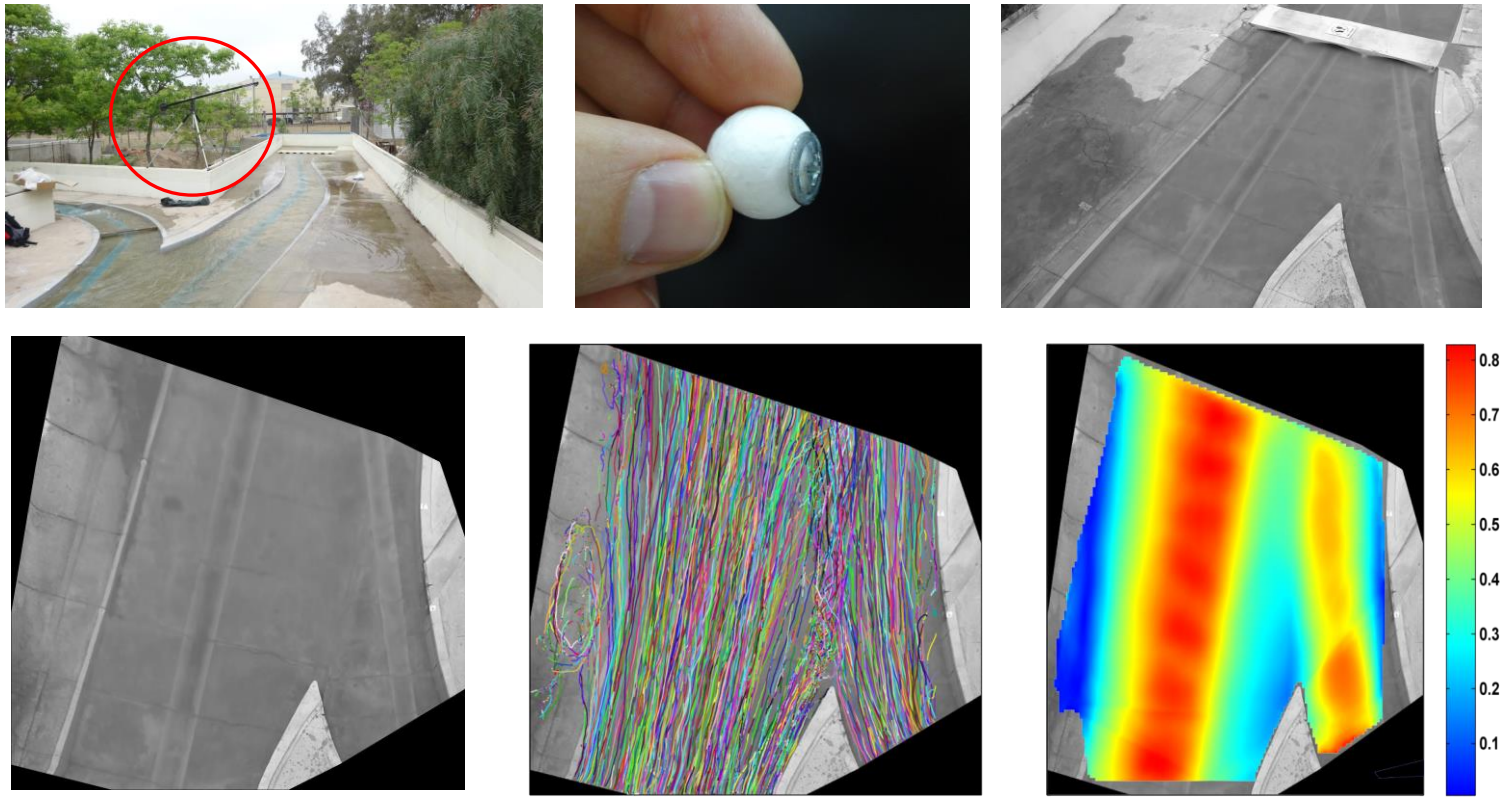
| Algorithm | Particle location | Matches possible | Matches found | Matches correct | Match yield (%) | Reliability (%) |
|---|---|---|---|---|---|---|
| Present work (tracking only) | Known | 4,042 | 4,039 | 3,927 | 97.23 | 97.15 |
| VAR (Ruhnau et al. 2005) | Known | 4,042 | 4,039 | 3,894 | 96.34 | 96.41 |
| EPTV (Mikheev and Zubtsov 2008) | Known | 4,042 | 3,863 | 3,823 | 94.58 | 98.96 |
| ICCRM (Brevis et al. 2011) | Known | 4,042 | NA | 3,980 | 98.46 | NA |
| Present work (particle identification + tracking) | Unknown | 2,095 | 1,846 | 1,761 | 84.06 | 95.40 |
| EPTV (Mikheev and Zubtsov 2008) | Unknown | 2,029 | 1,759 | 1,733 | 85.41 | 98.52 |
| VAR (Ruhnau et al. 2005) | Unknown | NA | 872 | 865 | NA | 99.20 |
| NRX (Ohmi and Li 2000) | Unknown | NA | 808 | 788 | NA | 97.52 |
| MF-EPS (Shindler et al. 2011) | Unknown | NA | 1,160 | 1,146 | NA | 98.80 |
| 2F-EPS (Shindler et al. 2011) | Unknown | NA | 1,123 | 1,112 | NA | 99.00 |



Source: Lei, Y. C.et al. (2012). A vision-based hybrid particle tracking velocimetry (PTV) technique using a modified cascade correlation peak-finding method. Experiments in fluids, 53(5), 1251-1268.

**Brevis, W.**, Niño, Y. and Jirka, G.H. (2011) On the integration of cross-correlation and relaxation algorithms for Particle Tracking Velocimetry: The ICCRM method. Experiments in Fluids, Volume 50, Issue 1, pp 135-147

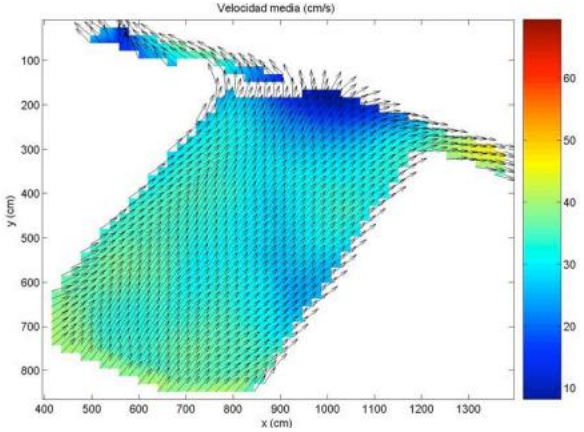
# Classical Image Velocimetry techniques: Controlled large-scale application




Source: Universidad Nacional de Córdoba, Argentina

# Classical Image Velocimetry techniques: Some challenges

- Current seeding techniques makes use of sawdust, which doesn't need to be recovered from a river or open channels:




Source: Universidad Nacional de Córdoba, Argentina

Higham, J. E., & **Brevis, W**. (2019). When, what and how image transformation techniques should be used to reduce error in Particle Image Velocimetry data? *Flow Measurement and Instrumentation*.

# Classical Image Velocimetry techniques: Some challenges

- In case of rivers with visible water surface fluctuations a quick technique to be used is “Optical Flow” which is much faster than standard correlation techniques

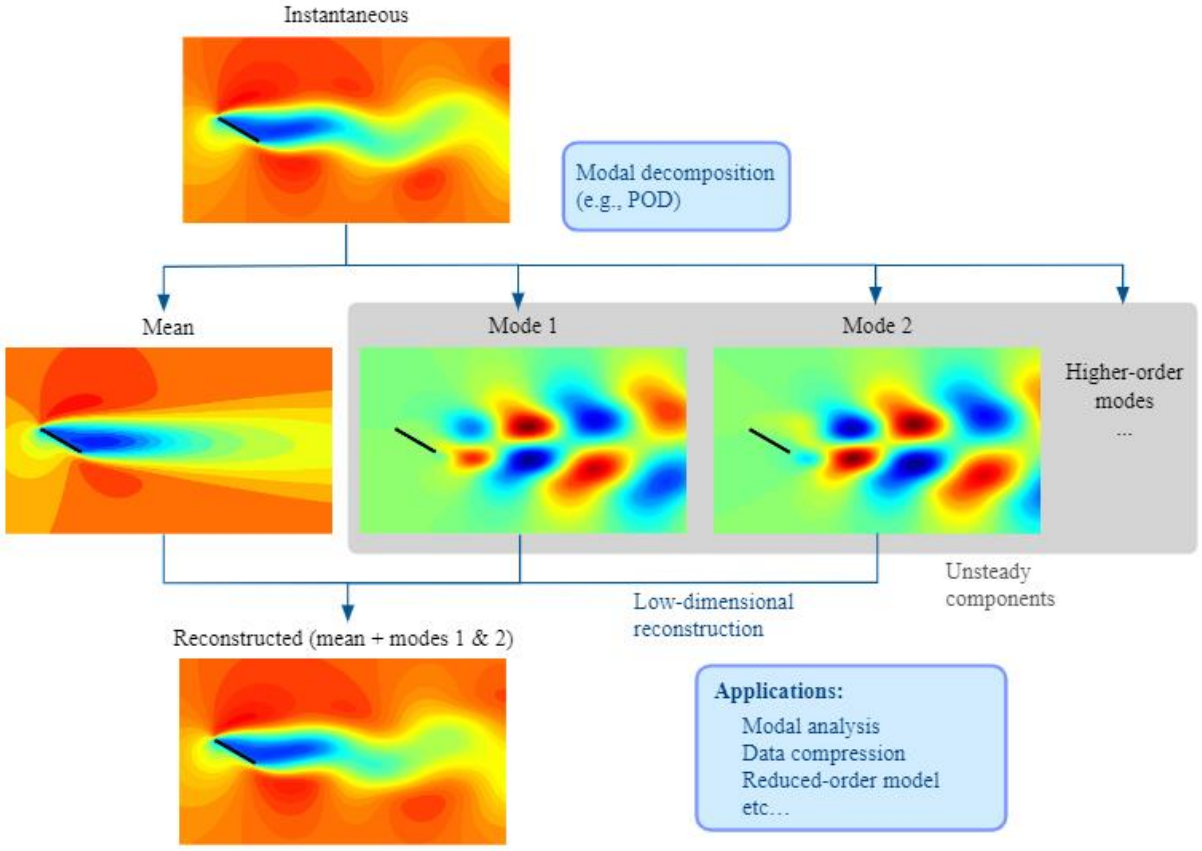
*Mella D, **Brevis, W**., Higham, J., Racic, V., Susmel, L. (2019) Image -based tracking technique assessment and application to a fluid-structure interaction experiment. in Part C: Journal of Mechanical Engineering Science*

# Classical Image Velocimetry techniques: Some challenges

- Implementation of algorithms for automatic detection of zones containing water (e.g. useful in mountain rivers)

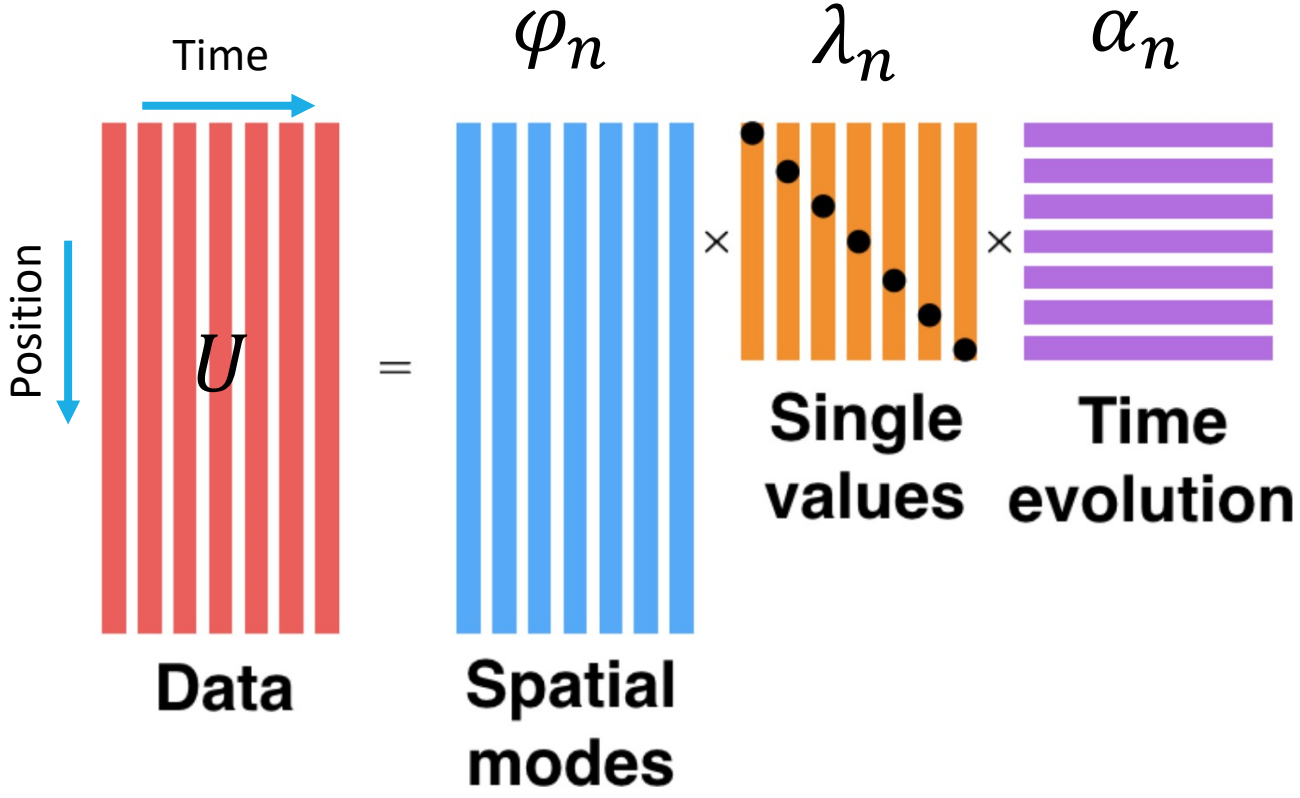
- Implementation of stereo reconstruction for simultaneous monitoring of water depth and discharge (optical flow)

# Flow visualizations: Methods for modal decomposition




Source: Taira et al (2017). Modal Analysis of Fluid Flows: An Overview. Arxiv 1702.01453

# Proper Orthogonal Decomposition (POD)




Higham, J, **Brevis, W.**, Keylock, C.J. (2018) Implications of the selection of a particular modal decomposition technique for the analysis of shallow flow. Journal of Hydraulics Research.

# Proper Orthogonal Decomposition (POD)

- It can be obtained via resolution of a problem of eigenvalues of the covariance matrix.

$$R = U \cdot U'$$

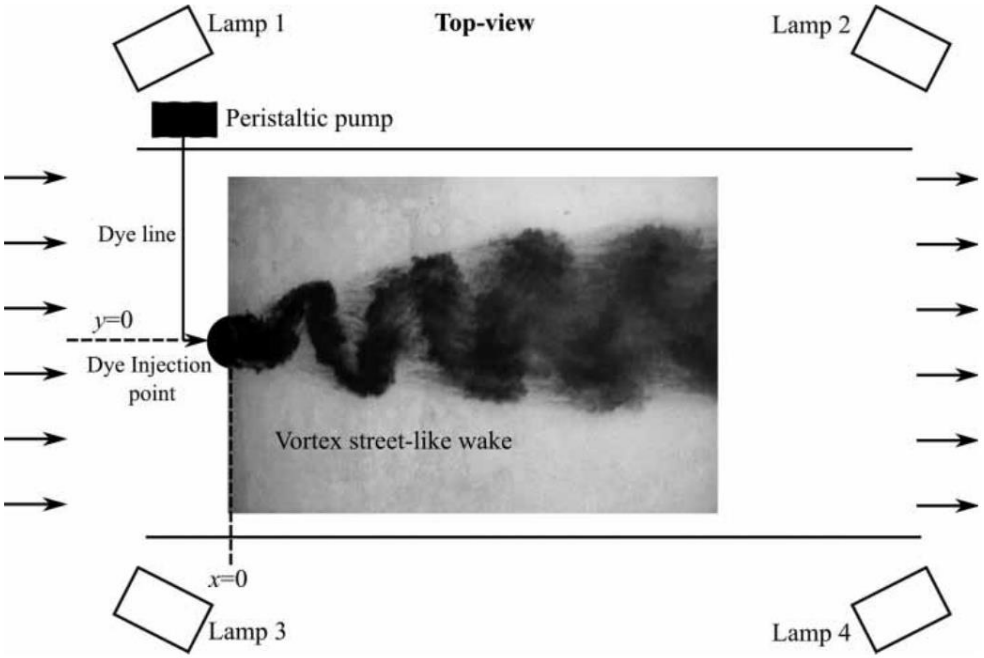
- Via resolution of a singular value decomposition (SVD)

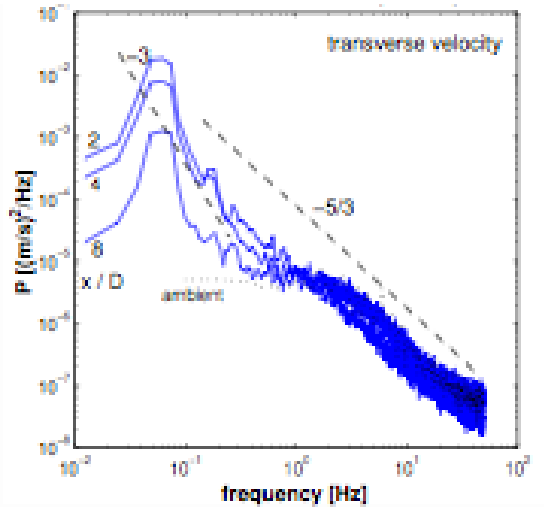
$[\varphi, \lambda, \alpha]$ = svd(U,'econ') → Matlab

$\varphi, \lambda, \alpha$ = np.linalg.svd(U, full_matrices=False) → Python

# Development of quantitative methods for analysing flow visualizations in shallow flows

Measurements with Laser Doppler Velocimeter in several longitudinal positions



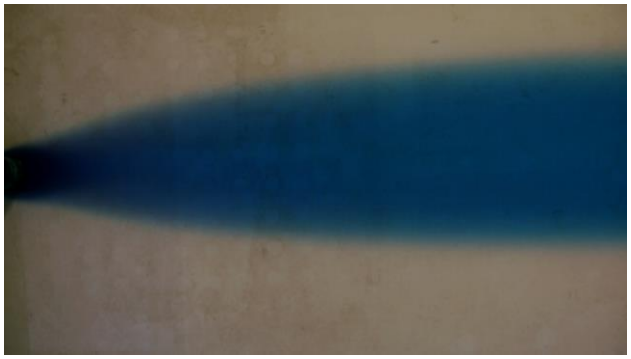

Source: Carmer, v,C. (2005)

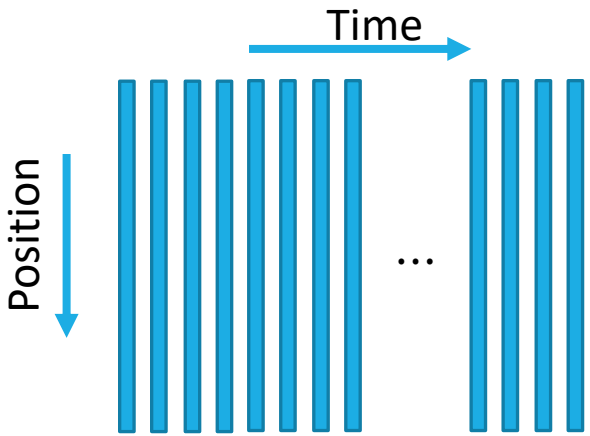
**Brevis, W.** and Garcia-Villalba, M. (2011) Proper Orthogonal Decomposition analysis of flow visualisations, a tool for the description of large scale shallow flows. Journal of Hydraulics Research. IAHR, Vol 49(5), pp 586-594

# Development of quantitative methods for analysing visualizations in shallow flows

Time Series Image Calibration (Image dewarping)

Average image calculation






- Subtraction of Average image
- Color scale reversal.

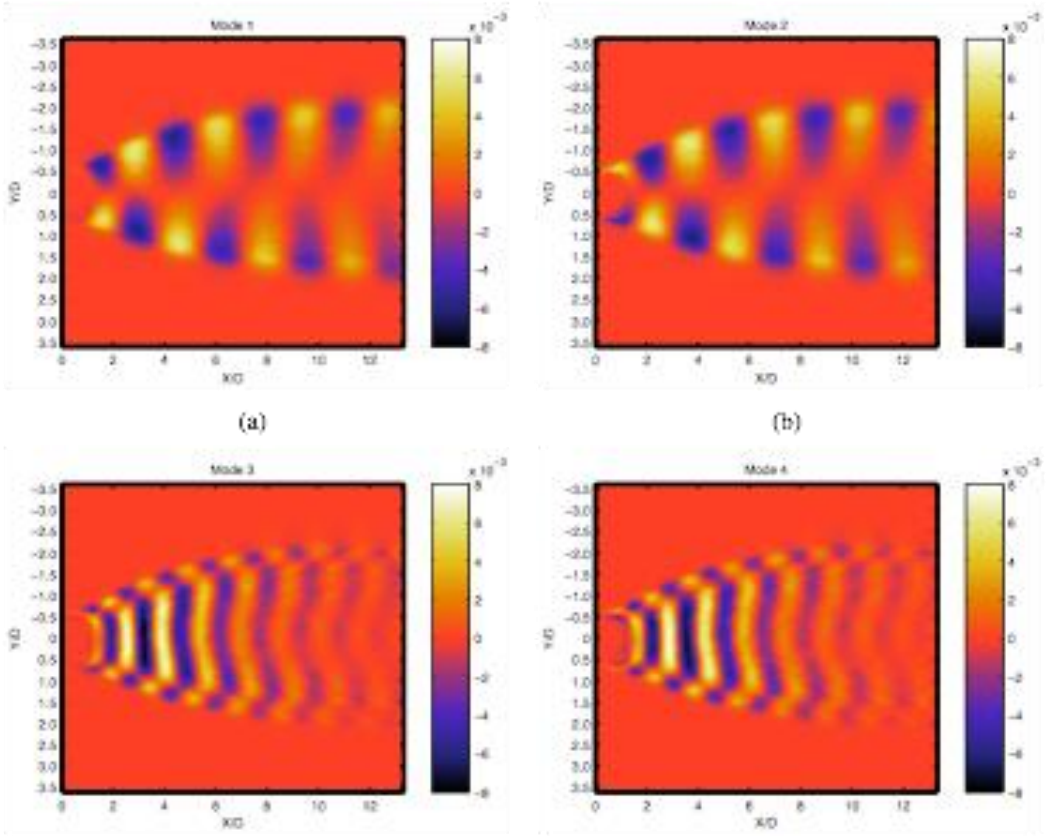
# Development of quantitative methods for analysing visualizations in shallow flows

Mode 1

Mode 2

Mode 1 and 2, 53%

$\lambda_n$



(a)

(b)

Mode 1 and 4, 61%

Spatial shape of modes

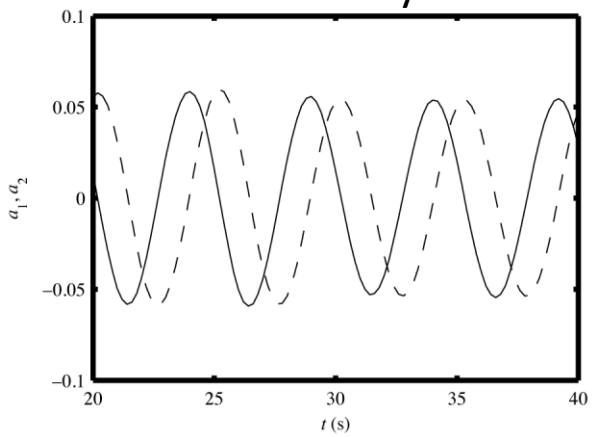
$\varphi_n$

Mode 3

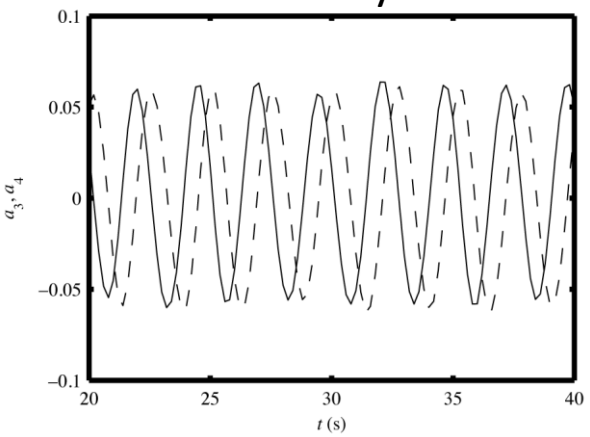
Mode 4

# Development of quantitative methods for analysing visualizations in shallow flows

Mode 1 y 2



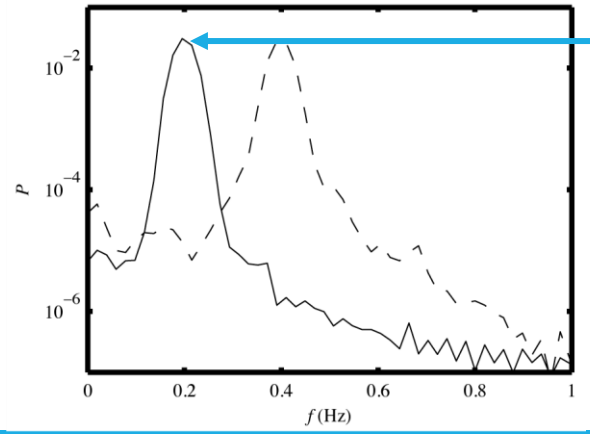

Mode 3 y 4



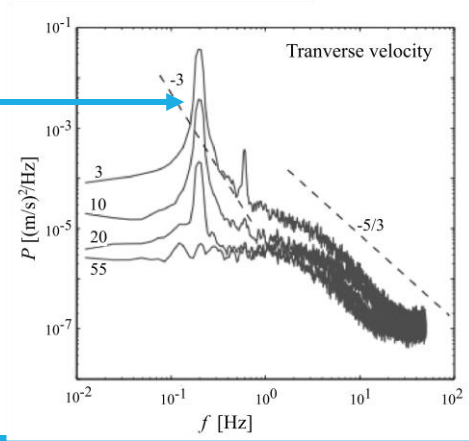

POD coefficients

$$\alpha_n$$

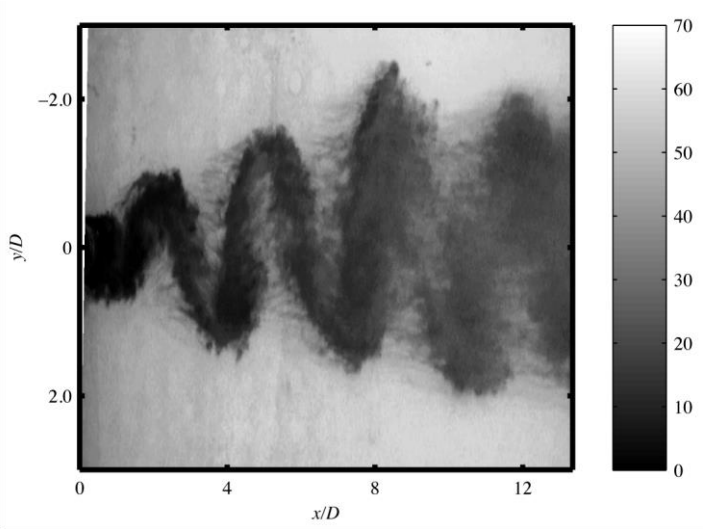
Coefficient spectra




Spectral estimation identical to that obtained with LDV



# Development of quantitative methods for analysing visualizations in shallow flows




Original image

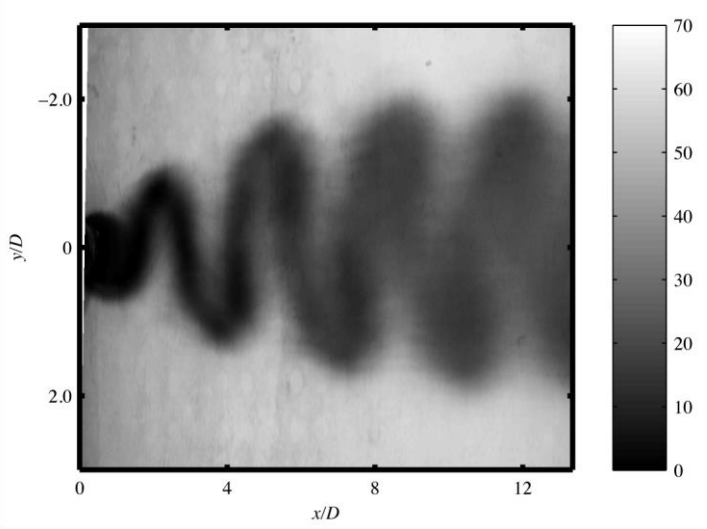



Image rebuilt with 4 first modes

# Applications in the field ?

Source: https://aquaticinformatics.com/blog/hydrology/chicago-river-green-hydrology/