



Growing
ideas
through
networks

An evaluation of **image velocimetry** techniques under **low flow** conditions and **high seeding densities** using **Unmanned Aerial Systems**.

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University
of Worcester



Activities of WG4

- Field Campaign – River Kolubara, Belgrade, Serbia (November 2018)
- Two STSMs
 - Italy (February 2019) and Newcastle (March and July 2019)
 - Focused on learning image-velocimetry workflow and techniques



Motivation

- Image velocimetry has proven an effective method for quantifying surface velocities in high flows (often within 10% of traditional techniques)
- Little research has focussed on low flow monitoring and the comparison of multiple algorithms to one set of environmental conditions

Within WG4 we have several experts of different algorithms

Aims

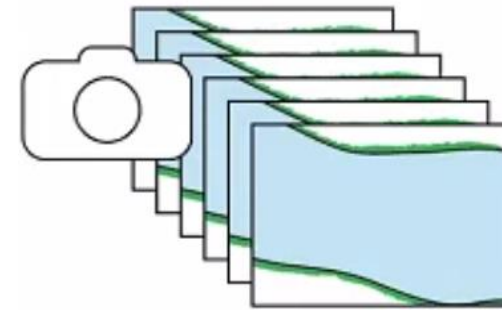
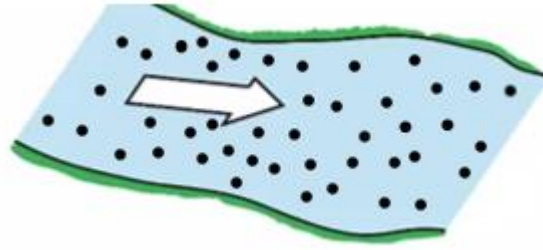
- Evaluate the sensitivity of parameterisation to five image-velocimetry algorithms during low flow conditions
 - Particle identification area and search lengths (Interrogation Area / Block size / Trajectory length)
 - Sub-sampling frame rate (feature extraction rate)
- Compare all algorithms to reference ADCP data

Algorithms

- Kanade-Lucas Tomasi (KLT-IV)
- Large Scale Particle Image Velocimetry (LSPIV)
- Large Scale Particle Tracking Velocimetry (LSPTV)
- Optical Tracking Velocimetry (OTV)
- Surface Structure Image Velocimetry (SSIV) / Discharge App

Basic working principle of Image Velocimetry

River flow with visible surface features

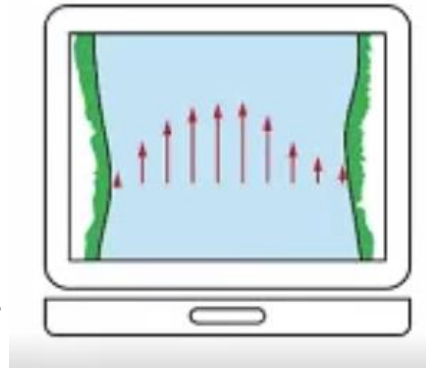


Image/ video sequence of river surface captured, using any camera sensor



Orthorectification of images through known locations of Ground Control Points

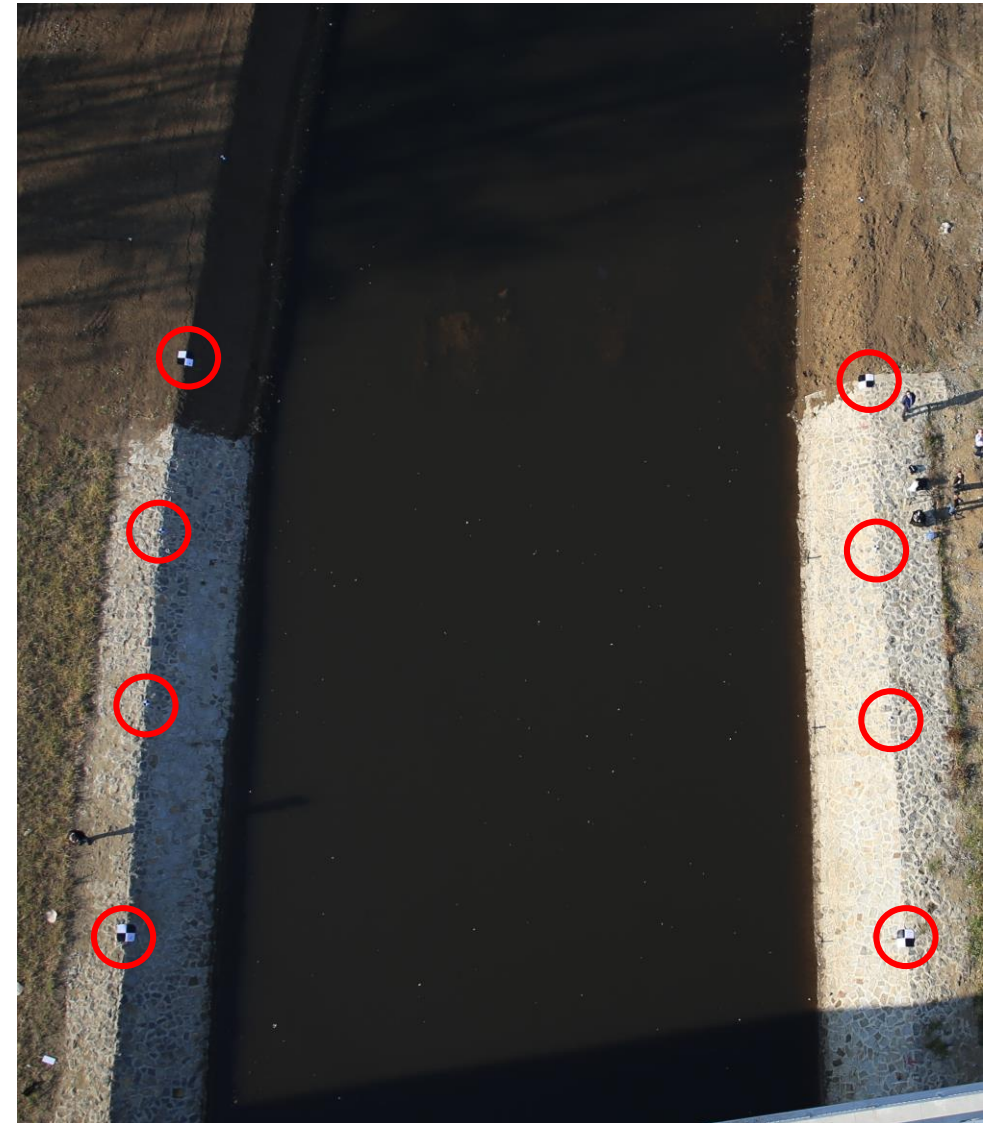
Surface velocities computed using image-velocimetry algorithm (LSPIV, STIV, PTV etc.)



Orthorectified images where all pixels are the same size and have Cartesian coordinates

Belgrade Field Campaign

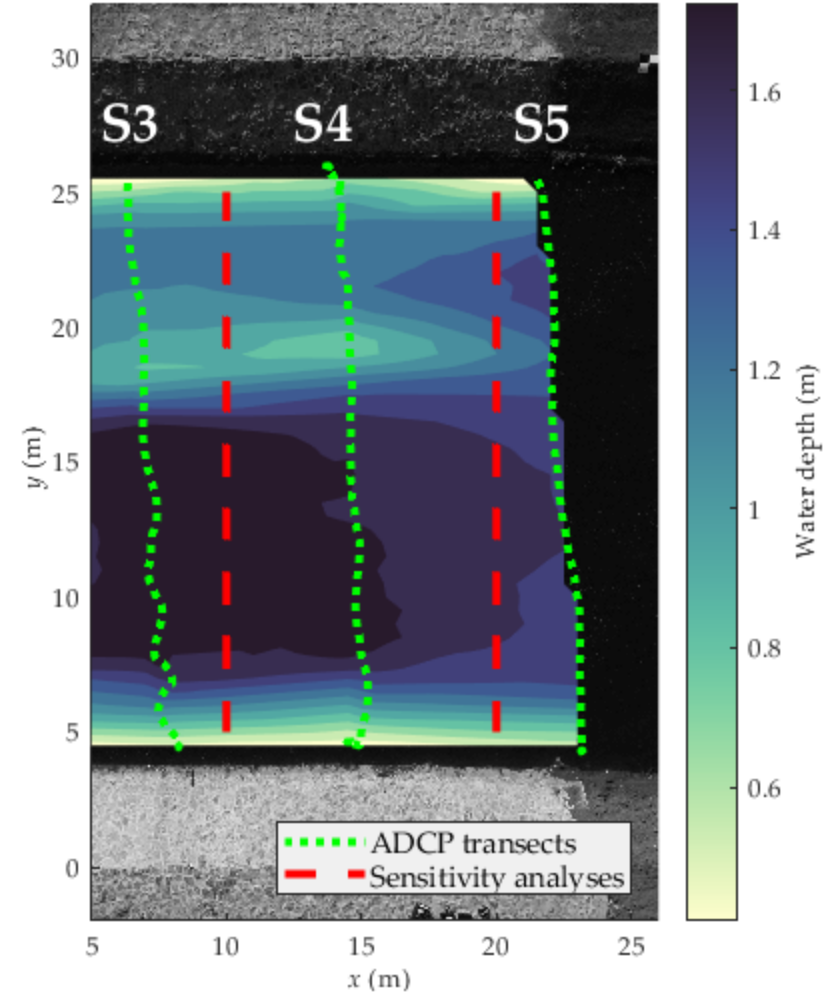
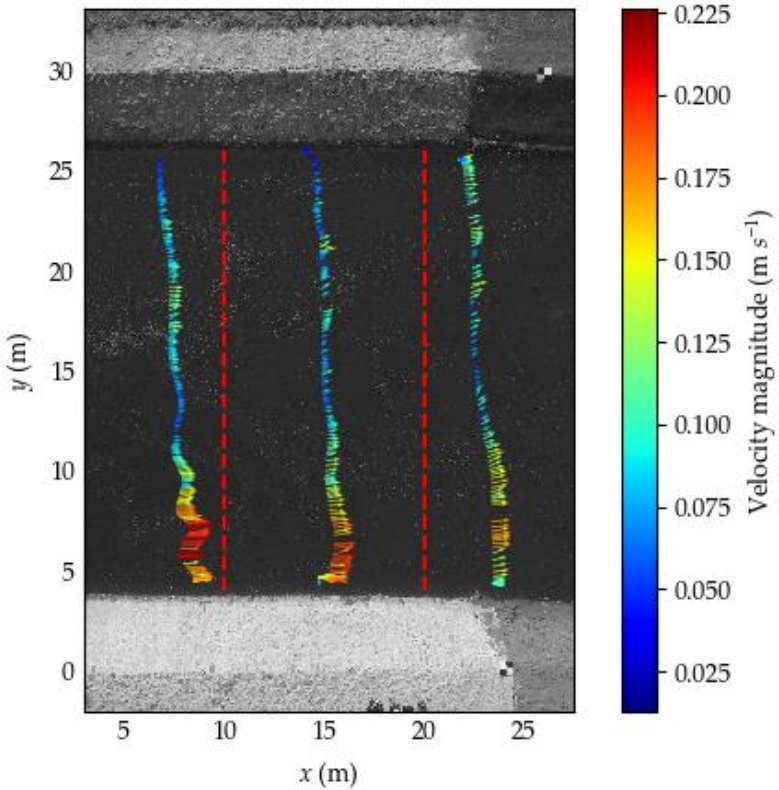
- DJI Phantom 4 Pro
 - 4k, 24fps
 - Sampling time reduced to 30seconds of video
- 10 GCPs
- Videos stabilised using KLT-IV
- Challenging low flow conditions ($\sim 0.14\text{m s}^{-1} / 3.4\text{m}^3 \text{s}^{-1}$)



- Seeding materials ~ 7 pixels in size



Reference Measurements and Bathymetry



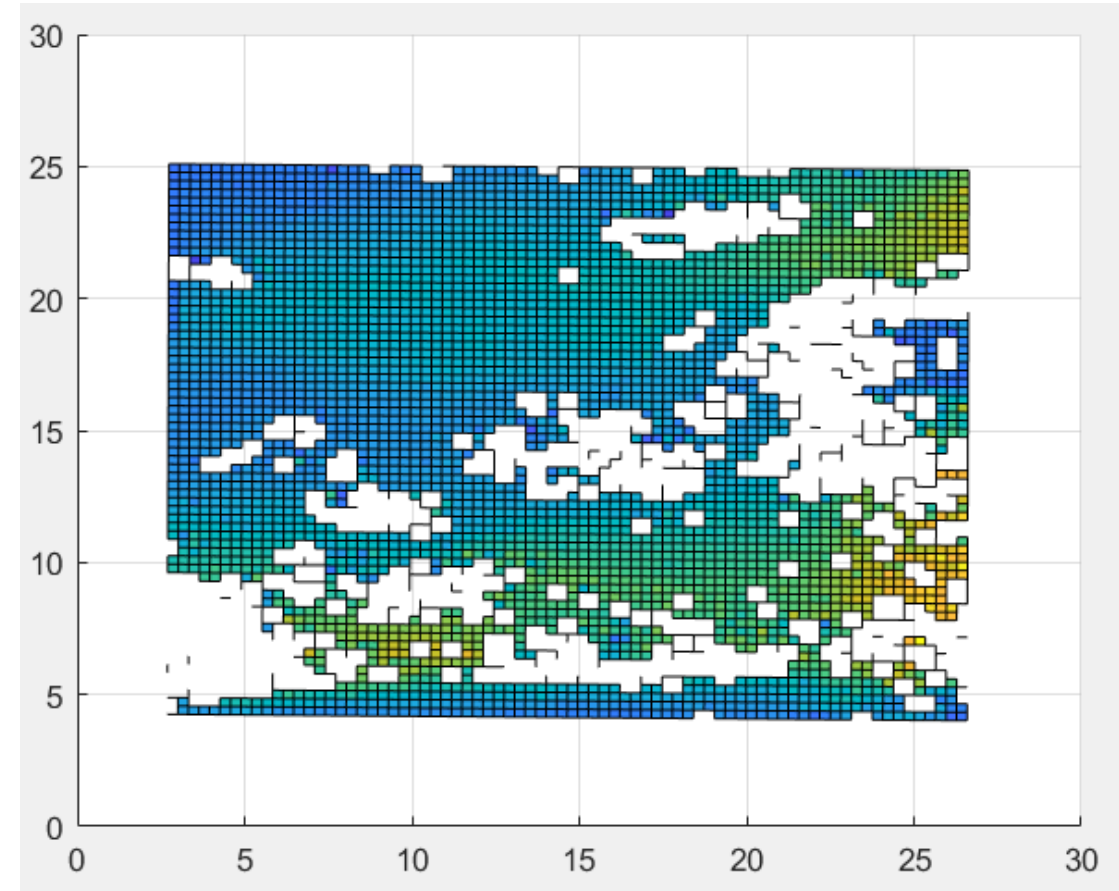
Sensitivity Analysis

- 4 feature extraction rates
 - 1, 2, 4, and 6 fps
- 3 Particle identification area and search area/length sizes

LSPIV, LSPTV and SSIV	KLT	OTV
32 ² , 64 ² & 128 ² pixel Interrogation Areas.	31 ² , 63 ² and 127 ² pixel Block sizes.	50, 100 and 200 pixel Trajectory lengths

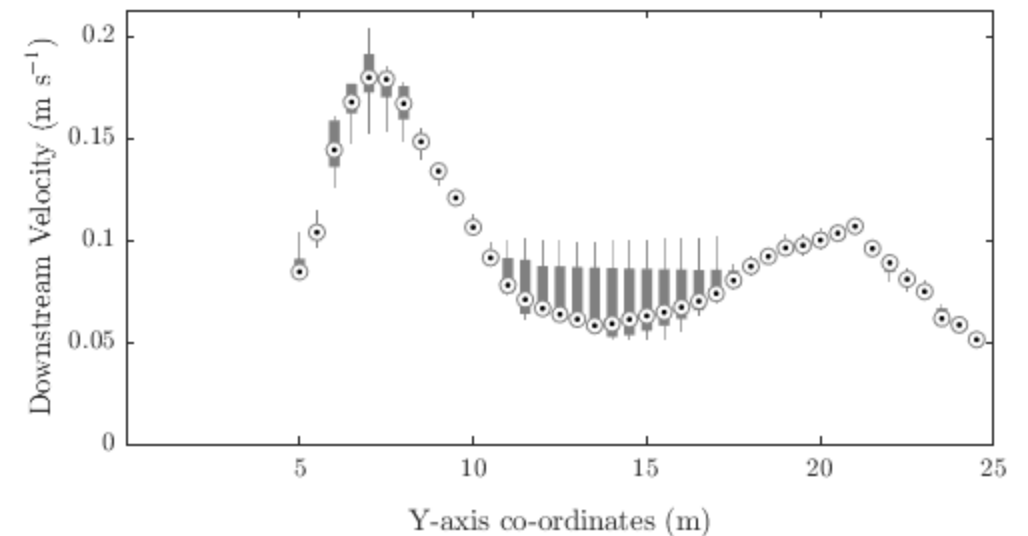
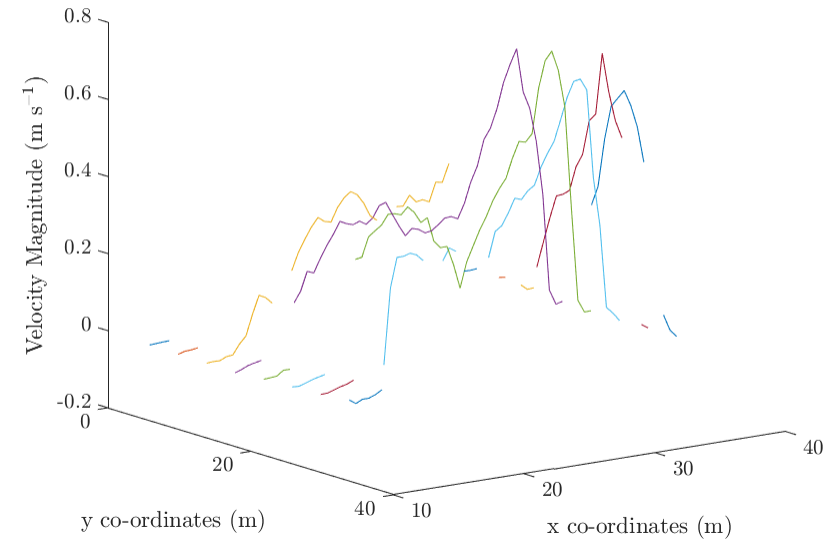
Sensitivity Scoring System

- All configurations processed through all algorithms
- Gridded to 0.5m cells – the average value within each cell is used for analysis = ~40 cells per cross-section
- A median value for each cell using input data from across the 12 different configurations was computed.



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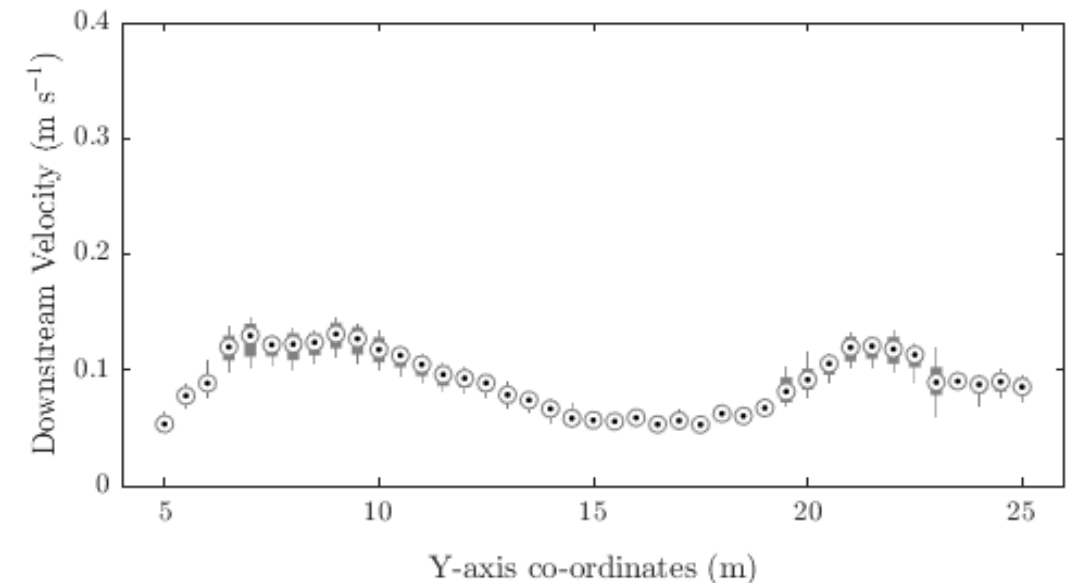
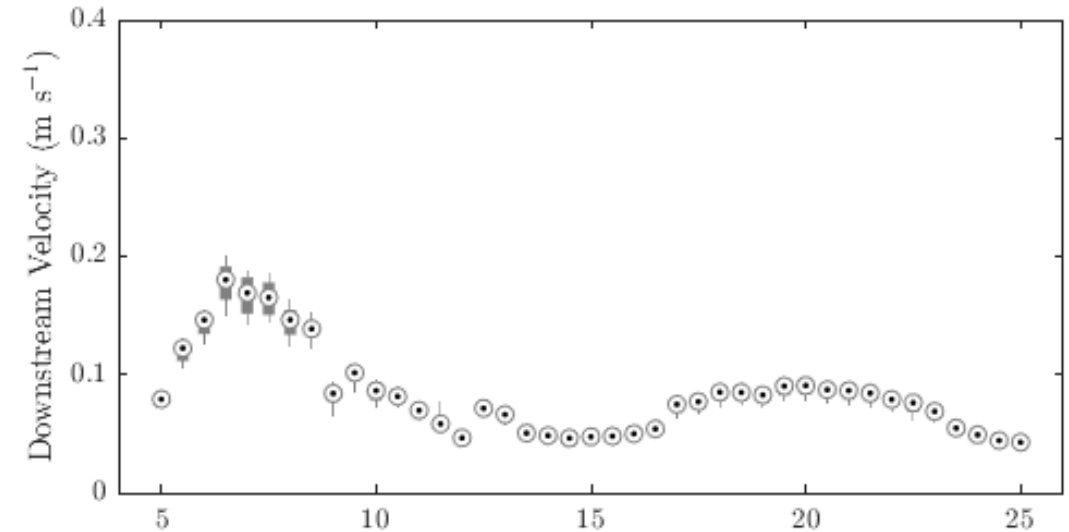


Sensitivity Scoring System

- A score is attached to each configuration for each cell based on the absolute deviation between the configuration specific velocity, and the median cell velocity.
- The sum of the absolute deviations throughout each cross-section provides the overall 'sensitivity score'
- **The lower the score – the less variable the algorithm is to changing parameters**

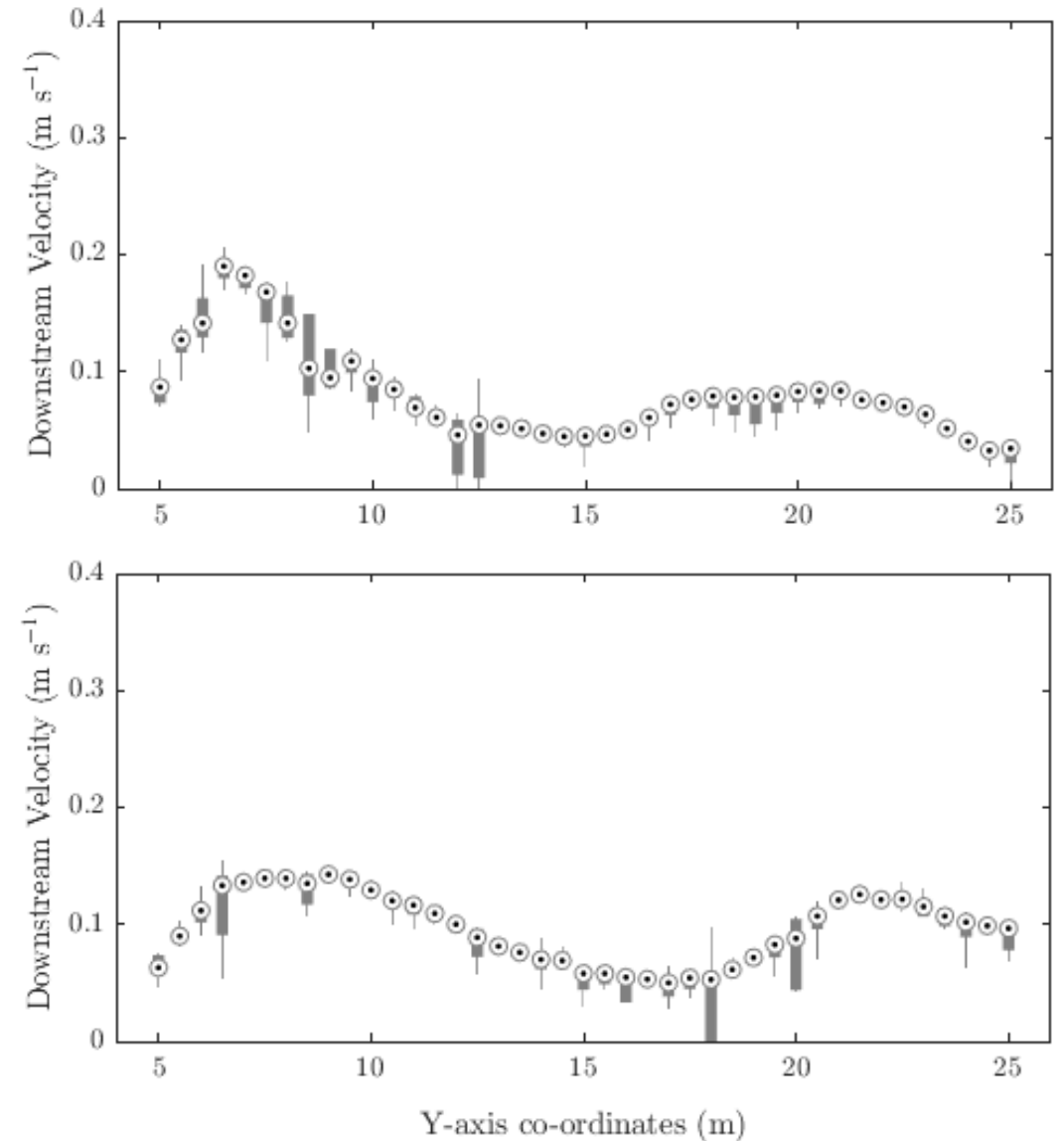
KLT

- Minimal deviations from mean throughout entire cross-sections
- Highest variations occur in higher flow velocities



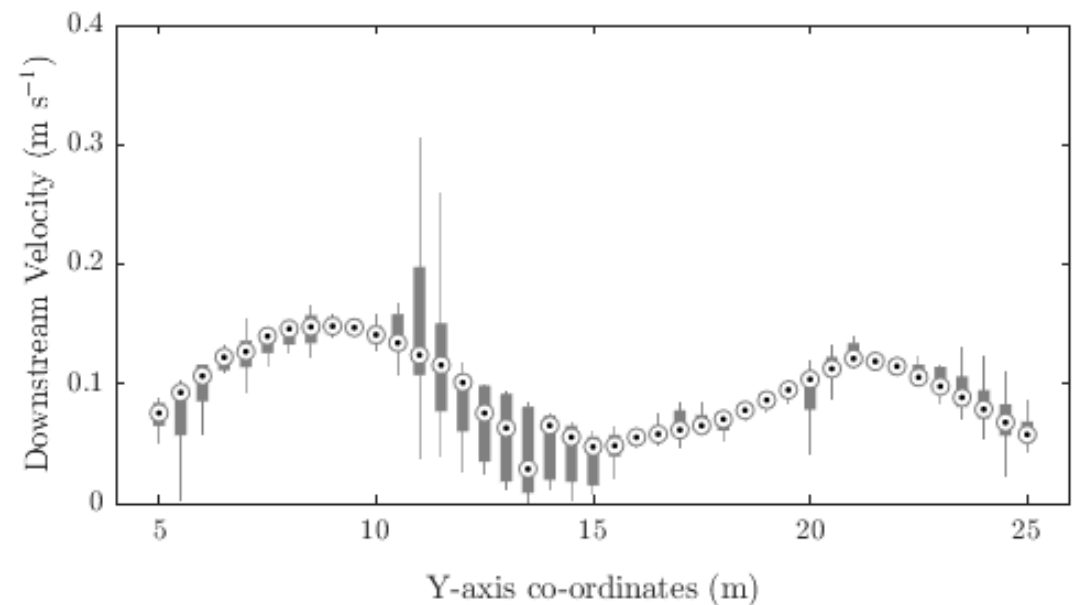
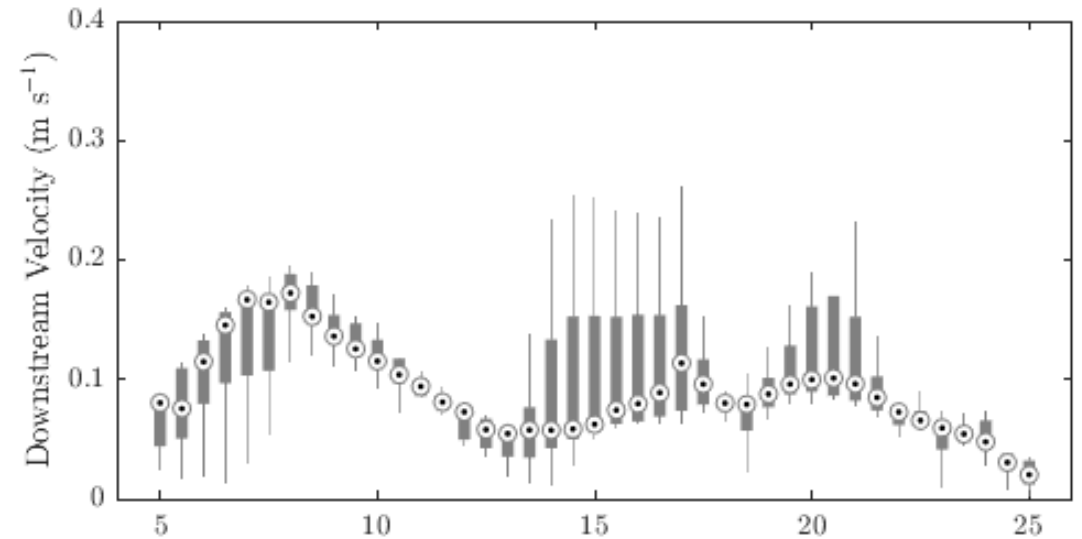
LSPIV

- Higher degree of variation when compared to KLT, however similar cross-sectional profiles
- Variability occurring predominantly in higher flows



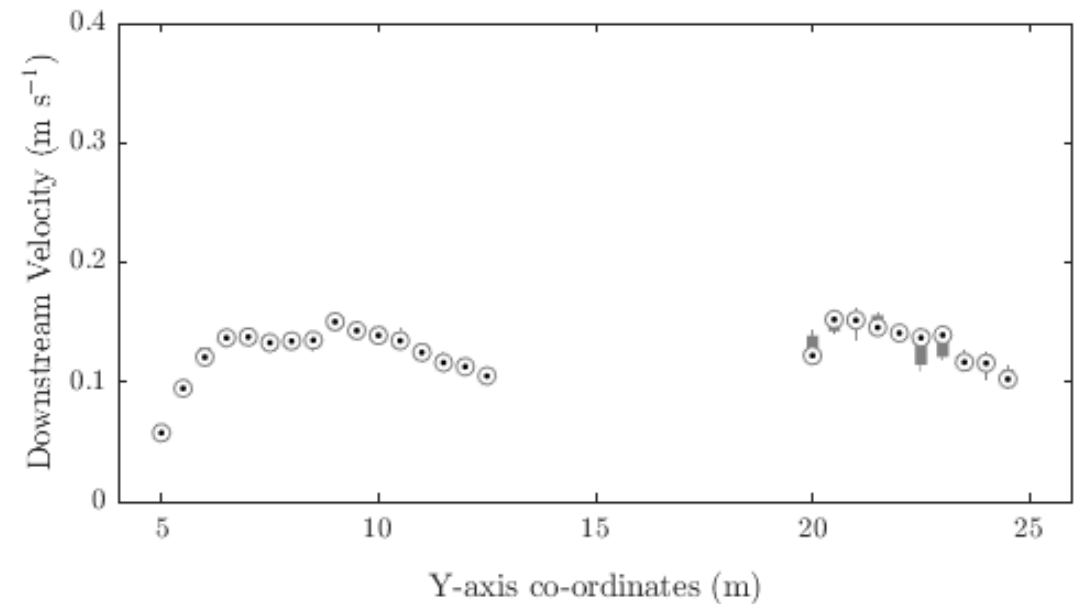
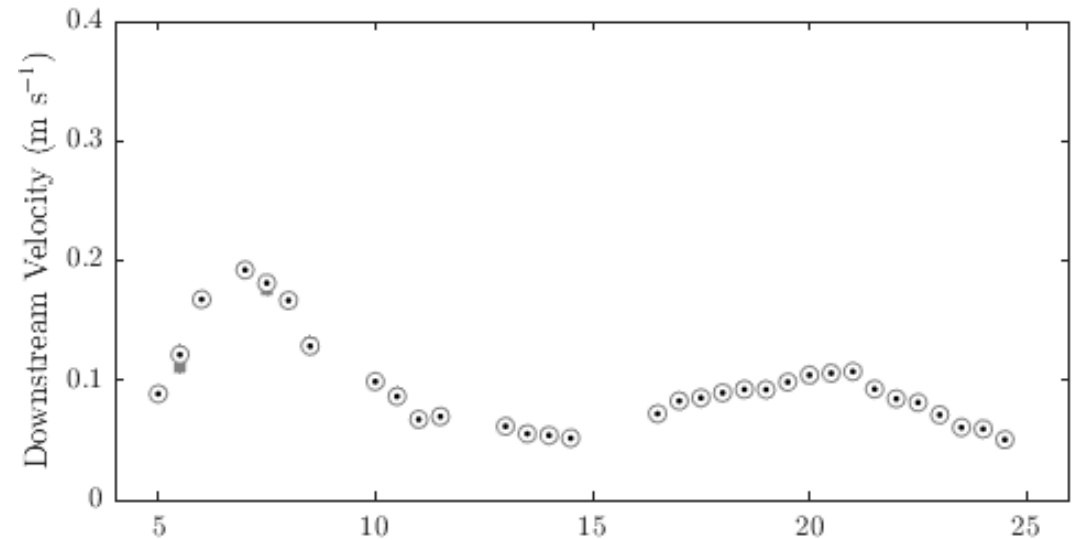
LSPTV

- Most sensitive algorithm to parameterisation
- Typically undergoes more rigorous pre and post processing to filter spurious results



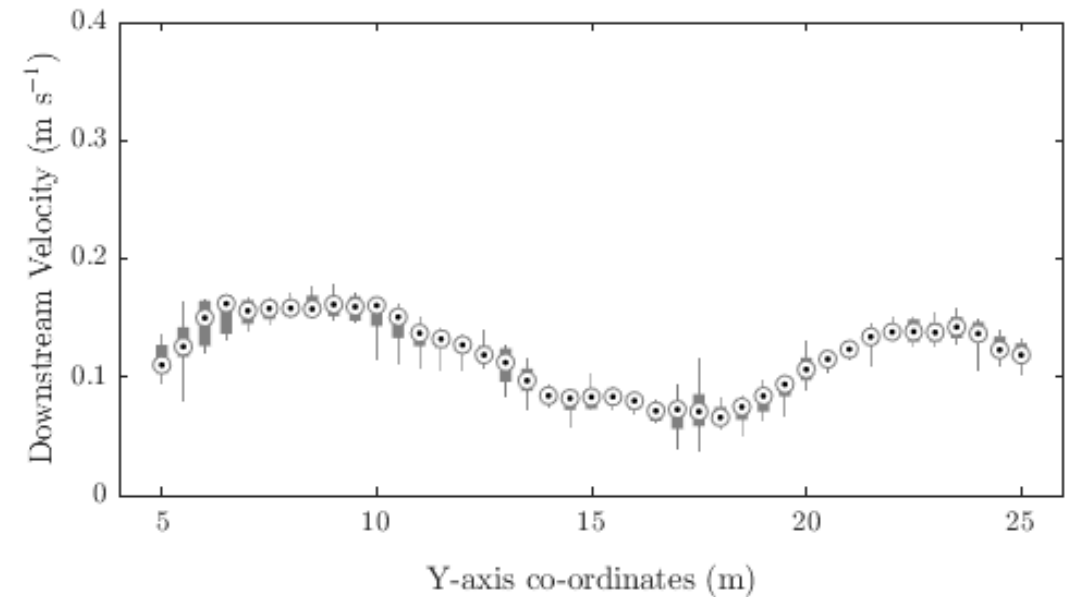
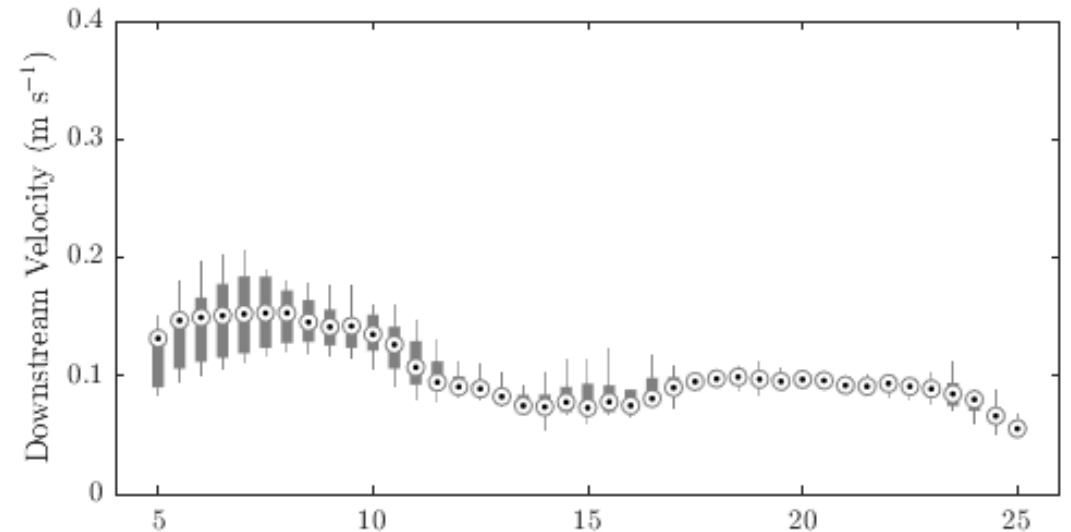
OTV

- Insensitive to changing parameters
- Gaps in the Analysis (Trajectory lengths)
- Further analysis is to be continued



SSIV

- Higher variation in faster surface velocities
- For cross-section 20m very little variation for all configurations



C1 = 32px IA / 31px Block size / 50px Trajectory
 C2 = 64px IA / 63px Block Size / 100px Trajectory
 C3 = 128px IA / 127px Block size / 200px Trajectory

Sensitivity Scores

		1fps			2fps			4fps			6fps		
		C1	C2	C3	C1	C2	C3	C1	C2	C3	C1	C2	C3
KLT	10m	0.124	0.130	0.126	0.078	0.064	0.080	0.066	0.060	0.059	0.194	0.192	0.191
	20m	0.215	0.162	0.228	0.123	0.076	0.135	0.096	0.103	0.098	0.252	0.282	0.252
OTV	10m	0.128	0.150	0.384	0.222	0.405	0.176	0.607	0.172	0.087	0.114	0.167	0.373
	20m	0.157	0.362	0.115	0.251	0.203	0.261	0.371	0.522	0.150	0.280	0.290	0.354
LSPIV	10m	0.338	0.129	0.190	0.105	0.069	0.163	0.256	0.311	0.093	0.143	0.106	0.126
	20m	0.237	0.229	0.094	0.227	0.191	0.165	0.185	0.167	0.054	0.072	0.212	0.062
LSPTV	10m	0.407	0.588	1.075	0.352	0.498	1.989	0.366	0.580	3.007	0.395	0.895	5.325
	20m	0.313	0.309	1.239	0.241	0.552	1.120	0.198	0.566	2.533	0.202	0.625	1.902
SSIV	10m	0.315	0.267	0.247	0.144	0.082	0.210	0.206	0.107	0.131	0.313	0.380	0.483
	20m	0.654	0.146	0.152	0.191	0.147	0.149	0.178	0.131	0.115	0.275	0.222	0.174

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Sensitivity Scores

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KLT	10m	0.124	0.130	0.126	0.078	0.064	0.080	0.066	0.060	0.059	0.194	0.192	0.191
	20m	0.215	0.162	0.228	0.123	0.076	0.135	0.096	0.103	0.098	0.252	0.282	0.252

Feature extraction rates of 2fps and 4fps provide less variability than 1fps and 6fps

Changing the block size does not affect overall results

C1 = 32px IA / 31px Block size / 50px Trajectory
 C2 = 64px IA / 63px Block Size / 100px Trajectory
 C3 = 128px IA / 127px Block size / 200px Trajectory

Sensitivity Scores

		1fps			2fps			4fps			6fps		
		C1	C2	C3	C1	C2	C3	C1	C2	C3	C1	C2	C3
OTV	10m	0.128	0.150	0.384	0.222	0.405	0.176	0.607	0.172	0.087	0.114	0.167	0.373
	20m	0.157	0.362	0.115	0.251	0.203	0.261	0.371	0.522	0.150	0.280	0.290	0.354

On average 50 pixel Trajectory provides the lowest sensitivity scores

C1 = 32px IA / 31px Block size / 50px Trajectory
 C2 = 64px IA / 63px Block Size / 100px Trajectory
 C3 = 128px IA / 127px Block size / 200px Trajectory

Sensitivity Scores

		1fps			2fps			4fps			6fps		
		C1	C2	C3	C1	C2	C3	C1	C2	C3	C1	C2	C3
LSPIV	10m	0.338	0.129	0.190	0.105	0.069	0.163	0.256	0.311	0.093	0.143	0.106	0.126
	20m	0.237	0.229	0.094	0.227	0.191	0.165	0.185	0.167	0.054	0.072	0.212	0.062

128 pixel interrogation area provides lowest scores on average

C1 = 32px IA / 31px Block size / 50px Trajectory
 C2 = 64px IA / 63px Block Size / 100px Trajectory
 C3 = 128px IA / 127px Block size / 200px Trajectory

Sensitivity Scores

	1fps			2fps			4fps			6fps		
	C1	C2	C3	C1	C2	C3	C1	C2	C3	C1	C2	C3

32 pixel interrogation area provides lowest sensitivity scores on average

LSPTV	10m	0.407	0.588	1.075	0.352	0.498	1.989	0.366	0.580	3.007	0.395	0.895	5.325
	20m	0.313	0.309	1.239	0.241	0.552	1.120	0.198	0.566	2.533	0.202	0.625	1.902

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Sensitivity Scores

	1fps			2fps			4fps			6fps		
	C1	C2	C3	C1	C2	C3	C1	C2	C3	C1	C2	C3

On average 64 pixel interrogation area provides lowest sensitivity scores

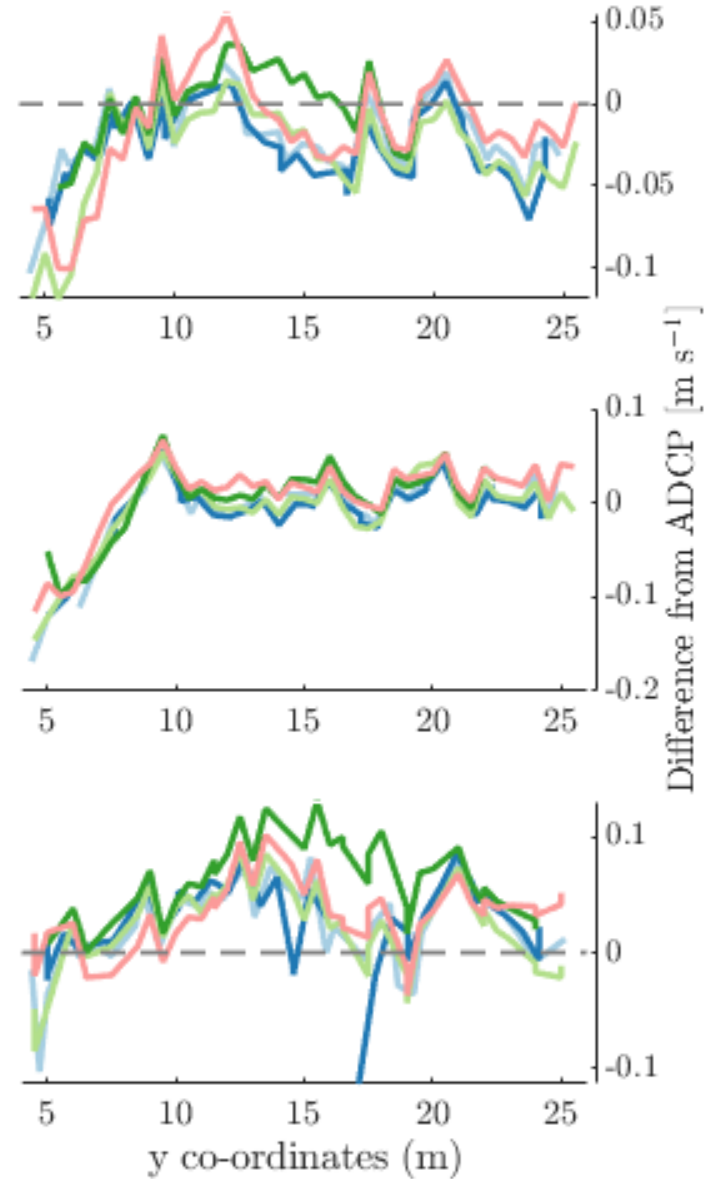
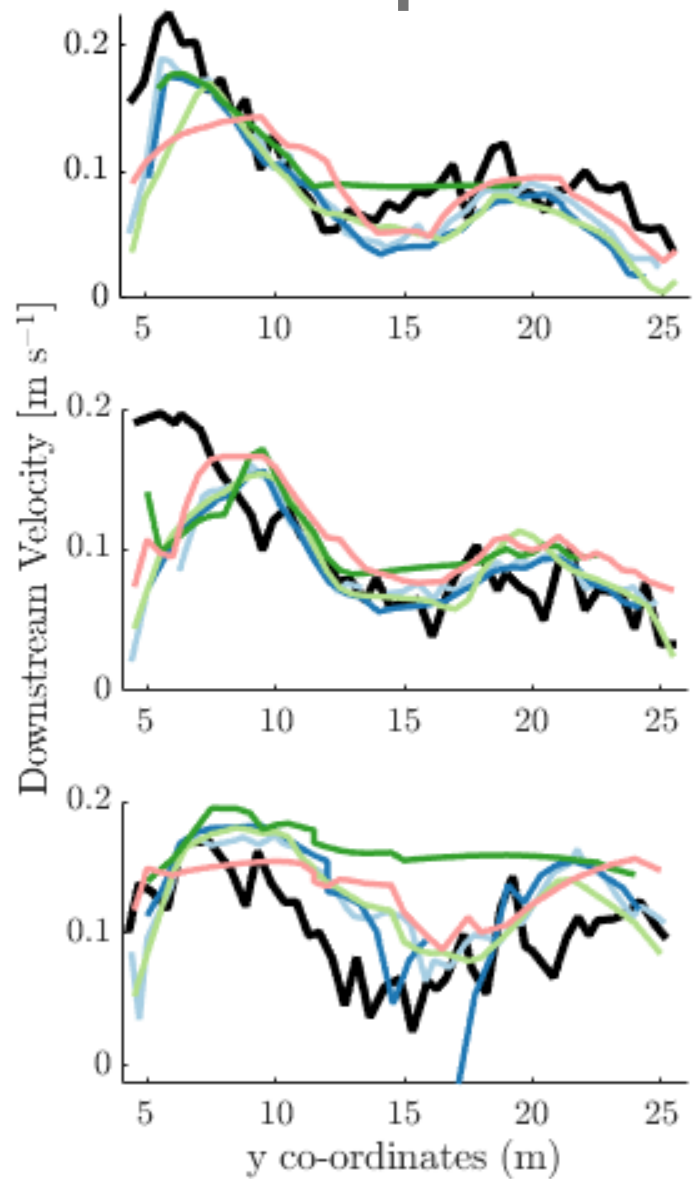
2fps and 4fps provide lower scores than 1fps and 6 fps

SSIV

10m	0.315	0.267	0.247	0.144	0.082	0.210	0.206	0.107	0.131	0.313	0.380	0.483
20m	0.654	0.146	0.152	0.191	0.147	0.149	0.178	0.131	0.115	0.275	0.222	0.174

Comparisons against ADCP

- ADCP ———
- KLT ———
- LSPIV ———
- LSPTV ———
- OTV ———
- SSIV ———



Conclusions

- KLT least sensitive algorithm to changing parameters within the conditions tested
 - Small variations due to feature extraction rate
- LSPTV most sensitive to parametrization, without any pre/post processing
- SSIV, LSPIV and KLT in best agreement with ADCP

Conclusions

- OTV – further analysis continues
 - Sensitivity analysis is recommending configurations which have a low resolution of data
- Lack of seeding material in the centre of the channel proving difficulties for OTV and LSPIV
- KLT-IV and SSIV (DISCHARGE App) = simplest GUI to use for a 'non-specialists'



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Thank you for listening
Questions?

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