hydralab+ Adaptation For Climate Change

Minutes of the Workshop on Industry and Innovation

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MINUTES OF WORKSHOP ON INDUSTRY AND INNOVATION

VENUE AND ATTENDEES

Venue: IH Cantabria

Date: 18-05-2017

Attendees: 46 participants: see participants' list.

Apologies: none

TOPICS FOLLOWING AGENDA

Item	Time	Subject
1	09:00	Welcome and introductions - James Sutherland, HR Wallingford
2	09:15	Technology development in HYDRALAB - Peter Thorne, National Oceanography Centre, Liverpool
3	09:30	Scanning 3D – 3C PIV - Olivier Eiff, Karlsruhe Institute of Technology
4	10:00	Velocity Measurements in Dantec Dynamics - Ivan Zadrazil, Dantec Dynamics
5	10:30	Coffee Break
6	11:00	Innovative non-invasive measurement systems for measuring shear stress - Rosaria E. Musumeci, University of Catania
7	11:20	Commercial acoustic sediment profiling - Andy Smerdon, Aquatec Group
8	11:50	Discussion on trends in the development of instrumentation - Chair: James Sutherland, HR Wallingford
9	12:20	Future Involvement in HYDRALAB+ Chair: James Sutherland, HR Wallingford

ACTION SUMMARY

No.	Name	Task	Deadline
1	All participants	Provide ideas for the instrumentation)	30-06-2017
2	J Sutherland	Organise 2nd workshop at 5th HYDRALAB event	31-05-2018
3	J Sutherland	Coordinate visit to JRA experiments	31-07-2017
4	G Smith	send ideas for engaging with industry to Sutherland	16-06-2017
5	Sutherland	Invite Zadrazil, Smerdon & Lohrmann to be on IEP	16-06-17
6	All participants	Suggest names of IEP members to Sutherland	30-06-2017

1 INTRODUCTION

James Sutherland (HR Wallingford) welcomed participants to the event and thanked IH Cantabria for organising the meeting and the invited speakers for attending the event. He explained that HYDRALAB participants have been working for many years and through different HYDRALAB projects to improve instrumentation, procedures for using this instrumentation and software for analysing the results. This is done to keep European laboratories at the forefront of technological developments. One of the tasks within HYDRALAB+ is to reach out to other communities, such as instrument manufacturers and contractors who are represented at this meeting. We are engaging with commercial instrument manufacturers to share the latest advances in instrumentation with them and to discuss how the science and technology of physical modelling should be improved. We are engaging with consultants, contractors and other organisations who might commission physical models in order to demonstrate to them that physical modelling is improving and we can now provide information that we could not in the past. This workshop focusses on developments in instrumentation and consists of an overview of instrument development in HYDRALAB, four presentations on ongoing developments and a discussion. Further presentations on instrument developments will be made in another workshop this afternoon.

2 TECHNOLOGY DEVELOPMENT IN HYDRALAB

Peter Thorne (National Oceanography Centre, Liverpool) presented an overview of recent instrument development, particularly that in HYDRALAB IV Joint Research Activity WISE and HYDRALAB+ JRA COMPLEX. Peter started by explaining how we need to know about the (spatially varying) flows, sediments and bedforms in order to understand sediment transport. Therefore we need to move away from point measurements to capture variations in space and time. Some examples of instrument development to help with this were given. These include:

- A linear array of acoustic transducers (such as in the BASSI instrument) or a 3D scanning acoustic ripple profiler can capture information on spatial variations in bed level that a single, stationary probe cannot.
- The acoustic concentration and velocity profiler can capture information on velocities, sediment concentration and seabed levels in a vertical profile through time, so can capture the convection of sediment above ripples by vortex shedding.
- The stereoscopic measurement of a seabed and swash wave surface through time has been captured using two cameras and a spatial array of points of light. This allows the change in levels in the swash zone caused by individual waves to be detected.

Prof Thorne then showed how arrays of instrument have been used in large flume facilities to complement each other and produce information on flows, concentrations and bedforms.

3 3D – 3C SCANNING PIV FOR HYDRAULIC FLOWS

Olivier Eiff (a long-term HYDRALAB participant, now at Karlsruhe Institute of Technology) gave an introduction to Particle Image Velocimetry (PIV) and explained the different methods for generating 2D light sheets and analysing results. After outlining some of the limiting considerations, he went on to describe some of the more advanced forms of PIV, including:

- Tomographic PIV that uses typically 4 cameras, 1 laser and no moving parts. Typical measurement volumes are less than 100 mm by 100 mm by 10 mm..
- Scanning classical PIV where the laser sheet is moved, so that a series of 2D velocity fields are recorded at varying distances from the camera.
- Multi-plane PIV which creates multiple, parallel light sheets, with a limited range of spacing.

Olivier then outlined the development of 3D – 3C PIV, which uses a high speed linear motor to shift the plane of the thin light sheet, allowing a sequence of images at different depths to be captured by a single, high speed camera. The frame rate can be 1,000 to 25,000 Hz and the laser sheet for one image overlaps to laser sheets from previous and next image. This technique also requires small seeding particles (less than sheet thickness) a single-peaked (typically Gaussian) light sheet intensity distribution. The technique allows an unambiguous construction of 3D particle images in a volume, so that 3D correlations can be calculated (by extension of 2D technique). A large number of small seeding particles is required. Three applications were demonstrated:

Shallow water dipoles, where the optical system of lenses, mirrors and a high speed linear motor were used to create the required vertical movement of the horizontal laser sheet. A measurement volume of 10 × 10 ×3.5 cm^3 was recorded each 0.2s with a resolution of 100 × 100 × 20 vectors. Visualisation tools were used to display the vorticity structure through time, illustrate that the flow is non-hydrostatic and show the growth of the negative pressure gradient behind the spanwise vortex..

Mountain wave breaking, which was illustrated using a stratified towing tank with a moving obstruction at the base to represent the mountain. The obstruction and measurement system moved together, over the tow length of 17 m to form a flying 3D – 3C PIV system.

Simulating atmospheric and oceanic stratified turbulence were created in Meteo-France CNRM stratified towing tanks and measured using 3D – 3C PIV with volumes up to 1 m x 1 m x 0.3 m.

Olivier then illustrated 3D - 2C PIV, where the laser sheet is moved continuously ad 2D PIV is undertaken on consecutive, overlapping sheets. There needs to be considerable overlap between sheets to reduce the number of false velocities. In the example shown, a 70% overlap of laser sheets produced 1% false velocities.

He concluded that 3D – 3C PIV takes advantage of the relatively slow variations in fluid flow in water to produce fully 3D-3C measurements of significantly larger volumes than the tomographic technique. The technique can measure fully turbulent flows and can resolve the flow in time currently at about 10 Hz.

4 VELOCITY MEASUREMENTS BY DANTEC DYNAMICS

Ivan Zadrazil (Dantec Dynamics) gave a short background on the company and its history before presenting a wide range of measurement techniques, including:

- Particle Image Velocimetry (PIV)
- MicroPIV
- Spray Imaging
- Laser/Phase Doppler Anemometry
- Laser Induced Fluorescence (LIF)
- Constant Temperature Anemometry
- DIC and Shearography

All can be applied to fluids or the related structures, such as propellers. He then presented an example of innovation in measurement: the development and installation of a Stereo PIV system in the towing tank of MARIN. This required an integrated, streamlined camera and light sheet probe that was easy to move between basins and relatively quick to set up. It included a retractable calibration system and submerged back-illumination system and used two 4M cameras and 2 quad core PCs.

Ivan then introduced a number of recent advances in particular instruments, including Diode Pumped Solid State Lasers, the Flow Explorer back-scatter LDA system with integrated optics and laser, a new Burst Spectrum Analyser processor and an all-in-one PDA probe. He went on to discuss current trends in the development of instrumentation, which he identified as

- Faster, larger and more detailed imaging, where there are trade-offs to consider. For lasers there is a trade-off between power and pulse frequency: you can have a 425 mJ laser at 10 Hz or a 8 mJ laser at 10,000 Hz (or combinations in between). For cameras the trade-off is between resolution and frame rate: you can buy a 29 Megapixel camera that operates at 5 Hz or a 1 Megapixel camera at 25,500 Hz.
- Complex measurements, such as the development of adaptive PIV, which adjusts the size and shape of the integration window based on seeding density and flow gradient, or adjusts the masking frame by frame.
- Uncertainty quantification, which can be based on peak ratio or particle disparity.
- Scanning PIV which is 2D-3C in multiple planes, using a traversing or scanning mirror including already developed visualization and data manipulation tools.
- Volumetric PIV which is a 3D-3C technique using volume reconstruction algorithms (from individual images) and volumetric velocity calculation. Requirements regarding data visualization and large data manipulation as well as computation time were discussed.
- Multi-parametric measurements. An example application was provided of waves hitting a seawall and overtopping. This could combine PIV with PLIF to measure multiple phases in the fluid, combine PIV with spray imaging to measure gas phases/droplets, use CTA to measure wall shear stress, DIC to measure vibration and deformation of the seawall, PIV and LIF to measure thin film thickness and velocity and TPIV and iPIV to measure interfacial velocity.

5 Innovative non-invasive measurement systems for measuring shear stress

Rosaria Musumeci (University of Catania) stressed the importance of direct measurements of wall shear stress since large flow resistances develop at boundaries. Rosaria described an innovative experimental technique, developed at the University of Catania, to estimate shear stresses within the water column by means of bioluminescence. This is the emission of light by some micro-algae known as dinoflagellates under the action of shear stresses induced by the flow.

She then went into more detail on their development of the use of ferrofluids to measure bottom velocities and shear stress. Ferrofluids are colloidal suspensions made up by nanoparticles of ferromagnetic materials, dispersed in a non-magnetic solvent, which are deformed by the application of a magnetic field. A drop of ferrofluid can be shaped into a 1 – 2 mm high spike by a permanent magnet under the seabed. This drop is then deformed by the flow and the deformation is measured optically or by induction.

The inductive readout strategy uses two planar wire coils on the seabed. The perturbation of the magnetic field generated by the movement of the ferrofluid drop is converted into a voltage change by the conditioning circuit. The optical readout strategy records the ferrofluid using a video camera. The shape of the ferrofluid drop is extracted from the video record and analysed to give the time-evolution of the main geometrical characteristics of the drop. The optical technique supports the inductive readout strategy. Both readout techniques have been calibrated under steady currents and regular surface waves.

The technique has now been used to measure bed shear stress at a mobile sand bed. The sand grains do not mix with the ferrofluid, but the support (including magnets) can become exposed.

Rosaria noted that the technique is promising and that they are trying to solve fundamental questions such as:

- how does the strength of the magnetic field affect performance?
- how do ferrofluids behave in the presence of different type of flows?
- how do ferrofluids perform in the presence of fixed and movable beds?

There are also a number of issues that need to be resolved to make ferrofluids easier to use, including how best to generate a spike and how to optimise the strength of the magnetic field.

6 Commercial acoustic sediment profiling

Andy Smerdon (MD of Aquatec Group) gave an overview of Aquatec Group and reported that they manufacture and sell equipment for observing suspended sediment and collecting both suspended and deposited sediment. He summarised the principles behind acoustic measurements of suspended sediment concentration, which are that suspended sediment particles in the water scatter sound, some of which is detected by the same transducer. For each particle size the scattering intensity increases with concentration. However, the scattering intensity also varies with particle size for each pulse frequency and the variation of scattering strength with particle size is different for each pulse frequency. This makes it difficult to calculate sediment concentration from the scattering intensity of the particle size distribution of the material in suspension is not known.

If a single frequency of acoustic pulse is generated, concentration can only be calculated if the particle size distribution is known. When multiple frequencies of acoustic pulses are generated, the variation in scattering intensity with particle size for each acoustic frequency can be used to determine the representative particle size, and this can be used to calculate concentration.

Andy then described the AQUAscat 1000 acoustic suspended sediment profiler, which transmits short pulses of sound at four frequencies between 0.3 and 5.0 MHz. Sound is sampled from 256 profile bins of variable size, giving a range of 0.64m to about 10 m. Pressure and temperature are also recorded.

The AQUAscat toolkit can be used for reading file details, applying corrections, writing data, calibration, modelling and data inversion. The data inversion functions available include explicit Acoustic Back Scatter (ABS) to suspended sediment concentration (SSC) inversion, an implicit inversion and direct calibration. The operational limits were described, including factors such as backscatter attenuation by high concentrations. The maximum range that can be measured varies with concentration, particle size, acoustic frequency and bin size. Higher frequencies are attenuated more with distance than lower frequencies, so for some cases only lower frequencies can be used.

Andy presented details of how the system constant is derived. Aquatec has its own 2.1 m high calibration tank. Calibration can be done with glass beads and acoustic results are compared to pump sampled data. The system constant was found to be independent of range beyond about 0.15 m from the transducer.

Example of AQUAscat use were presented from the Große Wellen Kanal at the FZK/LUH (DE), the Sea Palling detached offshore breakwaters (UK) the Fast Flow Facility at HR Wallingford (UK) and for the detection of a pulsed leak from a water pipe in water.

Planned developments include:

- Detailed analysis of attenuation for wash load;
- Interpretation of floc behaviour;
- Analysis of bimodal distributions;
- Evaluation of bubble influence; and
- Validation of high concentration performance.

Andy indicated that Aquatec would be interested in collaborating over lab and field experiments.

7 TRENDS IN THE DEVELOPMENT OF INSTRUMENTATION

James Sutherland introduced this discussion with some images of how wavemaker technology has advanced, from hand-powered paddles in the 1940s to today's multi-element digital wavemakers. He then noted how numerical modelling software had advanced as processing power has advanced and how the same trend can be observed in instrumentation. Velocity measurements have developed from

- propeller gauges measuring average values of one component of the flow over measurement volumes of the order of 10mm in diameter to
- LDAs measuring time series of two components of flows at 10 - 100Hz and measuring volumes of the order of 1 mm, through to
- Volumetric PIV measuring three components of flows over volumes of 100 × 100 × 100 mm at 10 - 100Hz.

Each step has required more processing power to take the measurements, record the data, process the data and visualise the results.

Identified trends in instrumentation that are likely to continue are:

- Computers continue to get faster and HPC and GPUs are making greater computer power available, so we will be able to develop and use even more complex and detailed instrumentation.
- Instrumentation is becoming less intrusive. The use of acoustic and optical measurement techniques and the shrinking of electronics mean that instrumentation today provides less disturbance to the flow than it used to.
- The volumes of data being collected from instruments have increased rapidly. This suggests the need for greater training in data management (for example as a standard part of PhD training).
- The push to make data openly available (as in Horizon 2020) indicates the need to adopt standards for data and metadata, where a lot of data is in proprietorial formats at the moment.
- Instrumentation is being developed that will allow the measurement of more complicated phenomena. We are moving from measuring a single phase to measuring multiphase flows. This can be seen in the development of instrumentation for measuring water and sediment, or bubbles, water and sediment or concentration and velocity. The incorporation of biological elements is also to be expected.
- Instrumentation is being developed that increases the number of dimensions that can be measured at one. ADVs have progressed from measuring a single volume to measuring profiles. PIV has progressed from measuring 2D velocity maps at between typically 0.5 and 10 Hz to measuring 3D-3C (three components of velocity in three dimensions) at up to 1,0000 Hz depending on resolution.
- Multiple complex measurement devices are available and can be deployed to measure complimentary features of a hydraulic tests A hypothetical example is given by Zadrazil. Another example is the use of acoustic profilers to get a vertical distribution of velocity and concentration with a ripple profiler to get information about bedforms and conductivity

concentration meters to get bedload concentrations in previous HYDRALAB experiments.). This concentration of expensive resources can produce multi-dimensional datasets that provide more information than ever before. The resource requirements mean that few laboratories will be able to afford such arrays of kit, or the staff required to use them all, which implies the need for continued collaboration at a European level to ensure that the benefits from the continued development of advanced instrumentation are maximised.

Action 1: Participants were asked to consider what they would like to be measuring in 20 years and why. Examples can be sent to j.sutherland@hrwallingford.com.

8 FUTURE ACTIVITIES IN HYDRALAB

A second workshop will be held with instrument manufacturers at the 5th HYDRALAB Workshop Event in Catania in summer 2018 and they will be invited to attend one of the HYDRALAB JRA experiments to observe testing and potentially deploy some of their kit.

Action 2: J. Sutherland to organise workshop and invite representatives of instrument manufacturers (by 31 May 2018).

Action 3: J. Sutherland to coordinate instrument manufacturers visit to JRA experiments with leaders of JRAs COMPLEX and RECIPE (Agustin Sanchez-Arcilla and Stuart McLelland) and representative of the potential host laboratories (by 31 July 2017).

HYDRALAB+ is also setting up an Industrial Engagement Panel (IEP) to reach out to other communities, particularly

- consultants and contractors who might commission physical model tests and
- instrument manufacturers.

Present at the workshop was Greg Smith of van Oord Dredging and Marine Contractors, who has agreed to sit on this panel. Ivan Zadrazil (Dantec) and Andy Smerdon (Aquatec) indicated their willingness to continue engaging with HYDRALAB+ as has Atle Lohrmann (Nortek).

Action 4: Greg Smith to send his ideas for engaging with industry to James Sutherland: j.sutherland@hrwallingford.com (by 16 June 2017)

Action 5: J. Sutherland to invite Zadrazil, Smerdon and Lohrmann to be on the IEP (by 16 June 2017).

Action 6: All participants to send names of potential members of the panel to j.sutherland@hrwallingford.com (by 30 June 2017).

The workshop closed at 12:30.

PARTICIPANTS' LIST

Hydralab + **18/05/2017** Morning Session

Workshop Industry and Innovation

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6	Yoshiaki Kuriyama	Port and Airport Res. Inst.	[illegible]
7	Jose Alsina	IMPERIAL COLLEGE	[illegible]
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12	F. Staudt	FZK (LUH)	Staudt
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26

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32	ROSARIA ESTER MUSUMECI	UC	
33	Anne Middelbae	DHI	
34	Gregory Smith	Van Oord	
35	Chauchat Julien	CNRS	
36	HURTHER David	CNRS	
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38	MARIA IONESCU	GeoEcoMar	
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46	Andy Smerdon	Aquatec Group	

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