Experimental Laser Flux Imaging System

Test of an innovative method in the underwater cave system of Tulum/Mexico

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Contents

- Research context
- Problem statement
- Basic idea and set-up
- Modules and calibration
- Data (turbulences, interferences)
- Data processing
- Results and conclusion
  - time series, velocity fields
  - statistics
- Conclusion and next steps

Research Context: Project Xibalba

A) Study on structure, dynamics and development of the Ox Bel Ha karst conduit system with innovative numerical methods (University of Neuchatel)

B) Capturing relevant parameters/data with standard and innovative methods (University of Neuchatel, Geological survey of Austria, Amigos de Sian Ka'an):

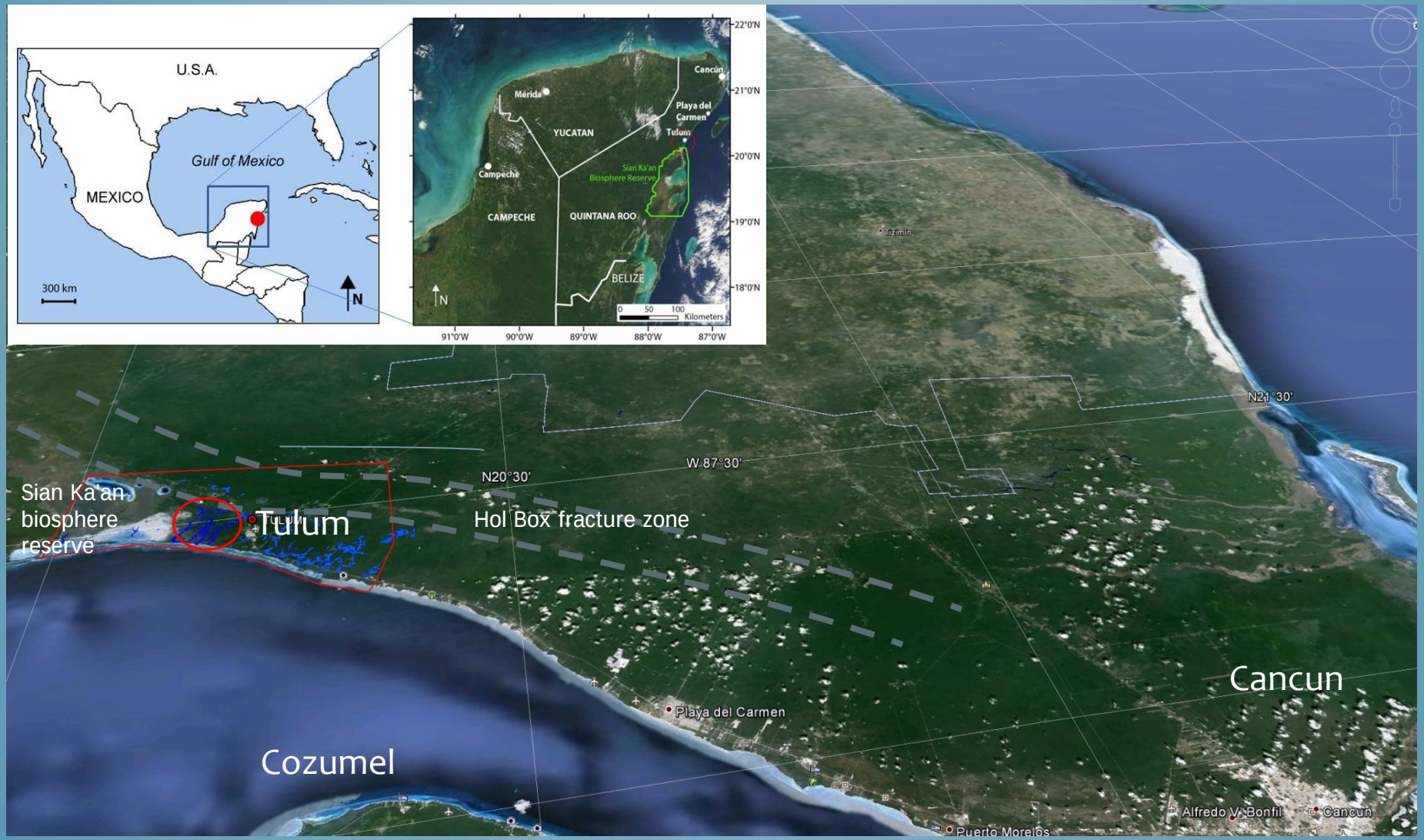
Conduit geometry: - Exploration diver surveys (dead reckoning)
- Geophysics (airborne EM, ERT, borehole, GPR)
- 3d laser scanning underwater

Water heads, tidal wave penetration:
- GPS
- Piezometry

Water chemistry: - on site analysis, laboratory analysis

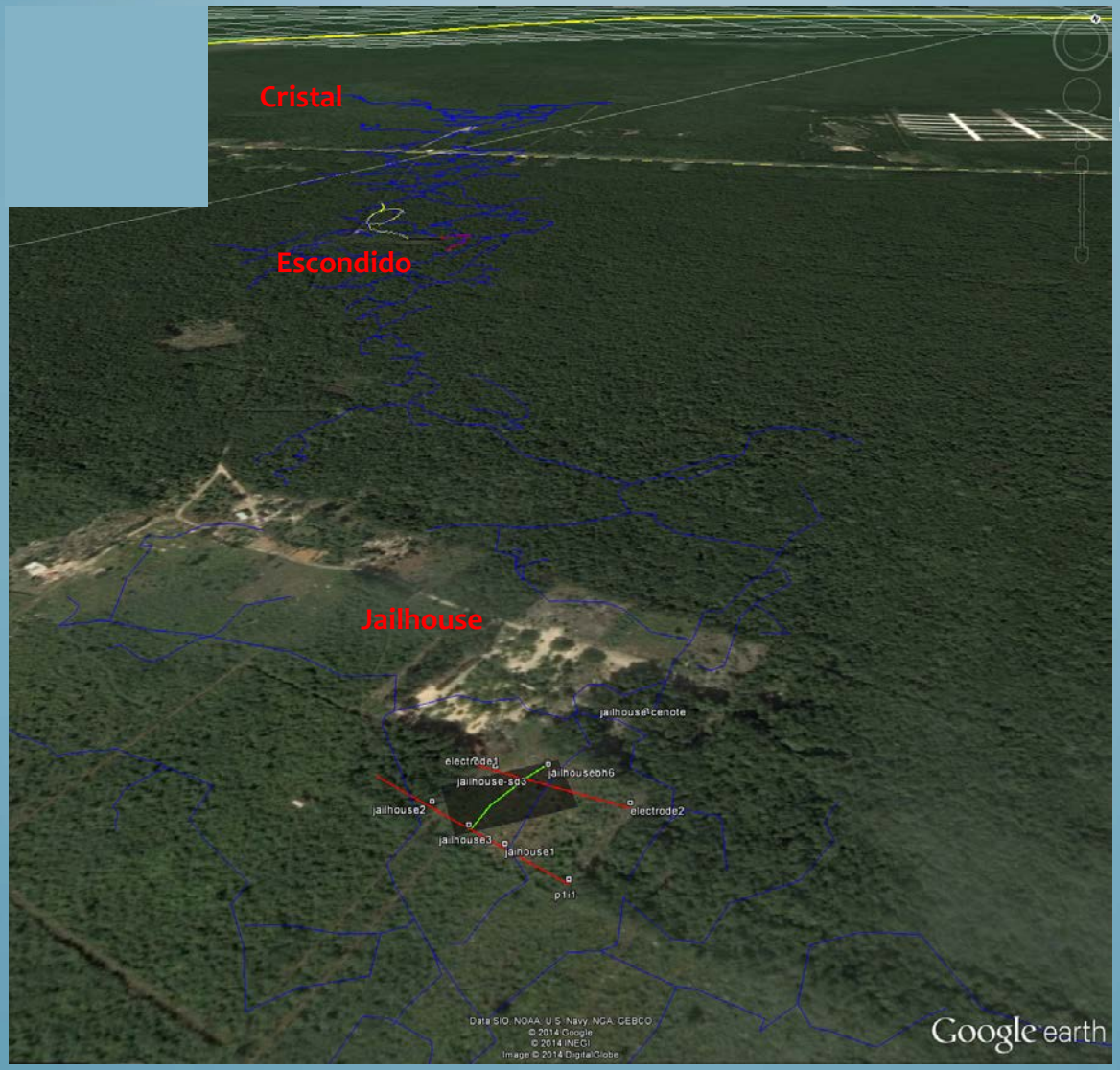
Velocity measurements:
- Tracer tests
- **Experimental Flux Imaging system**

SURVEY AREA


U.S.A.
Gulf of Mexico
MEXICO
300 km
N
Mérida
Cancún
Playa del Carmen
Tulum
YUCATAN
Campeche
Sian Ka'an Biosphere Reserve
CAMPECHE
QUINTANA ROO
BELIZE
0 50 100 Kilometers
22°0'N
21°0'N
20°0'N
19°0'N
18°0'N
91°0'W
90°0'W
89°0'W
88°0'W
87°0'W
Tizimin
N21°30'
W 87°30'
N20°30'
Sian Ka'an biosphere reserve
Tulum
Hol Box fracture zone
Cancun
Playa del Carmen
Cozumel
Alfredo V. Bonfil
Cancun
Puerto Morelos

TESTING SITE

Cenote Jailhouse - the Xibalba survey area for geometry and flux test measurements



⇨ Tulum

PROBLEM STATEMENT

- Acquisition of velocity data as input for numerical hydromodel
- Exact measurment of very low velocities < 2 cm/s (expensive)
- Non interfering => optical / laser method
- Long time logging => secure and robust set up
- Study of temporal and spatial variation => aerial measurement

TESTING SITE - DETAIL

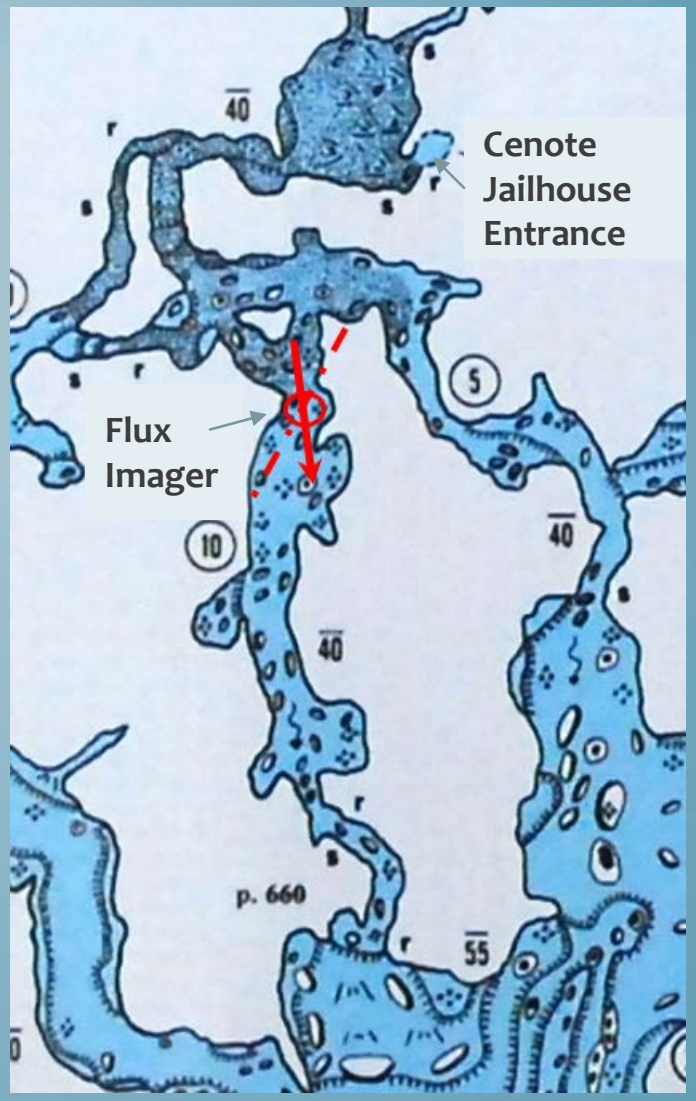
~ 50 meters south of Cenote Jailhouse

Water depth of conduit: 9 to 11 meters

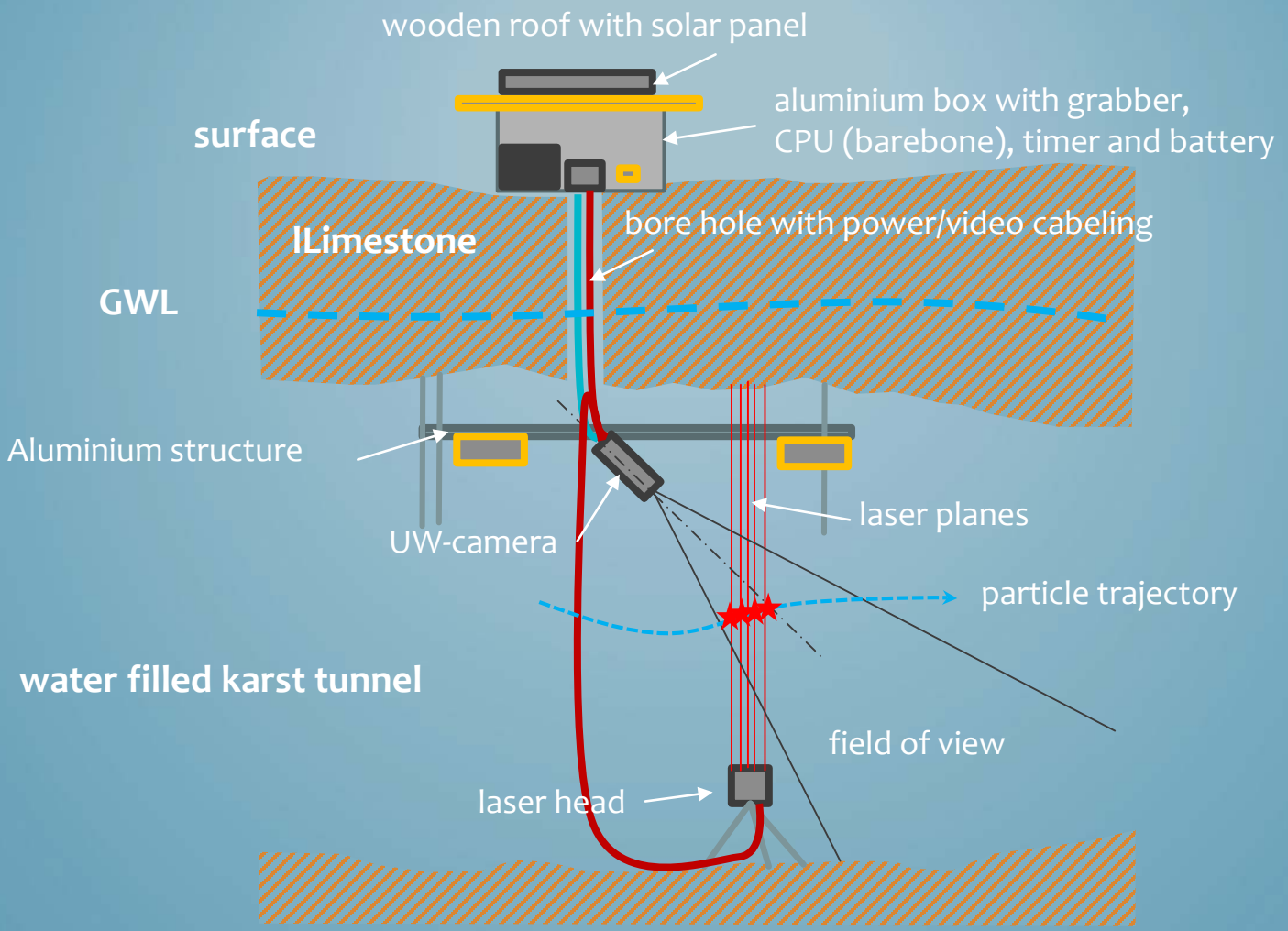
Red arrow: main current direction

Interupted line: axis of measurement system.

Positioned in fresh water top layer

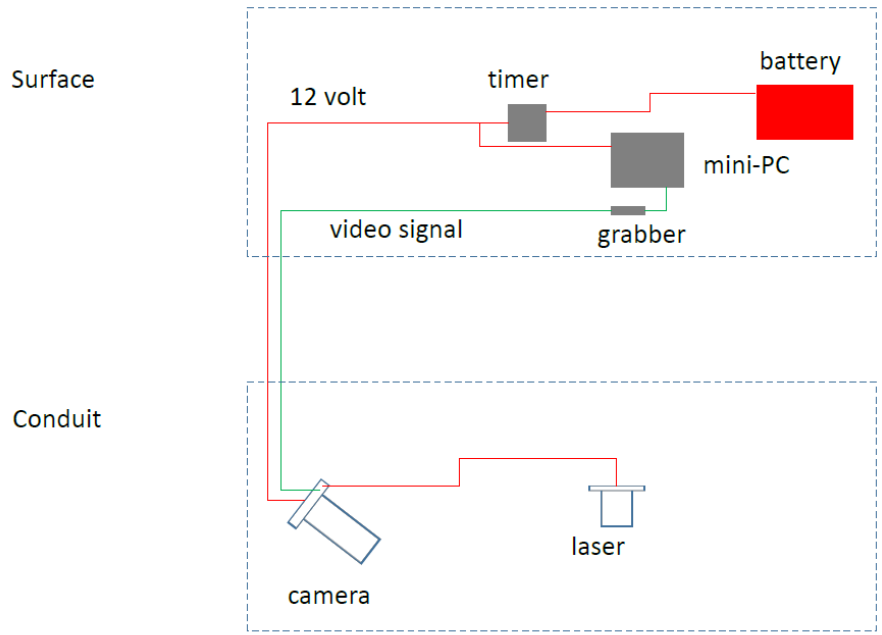


BASIC IDEA AND SET UP



COMPONENTS OF SET-UP

Flux Imager 2



Measurement sequence:

1 – timer:
⇒ mini-PC power on
⇒ camera power on
⇒ laser power on

2 – mini-PC:
⇒ auto start program
2.1 – program:
⇒ record movie
⇒ shutdown mini-PC

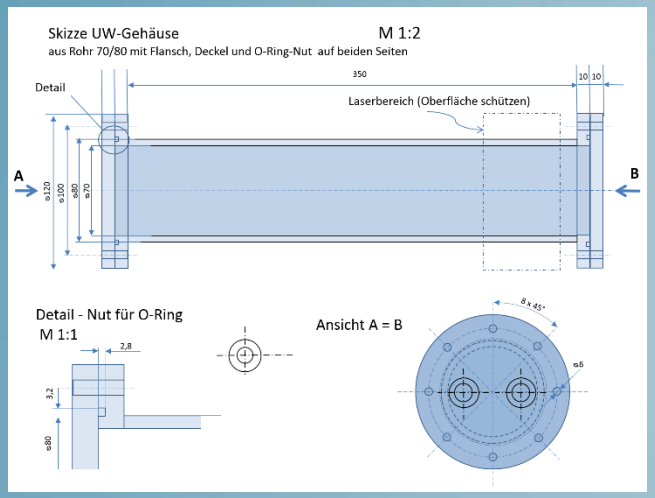
3 – timer:
⇒ mini-PC power off
⇒ camera power off
⇒ laser power off

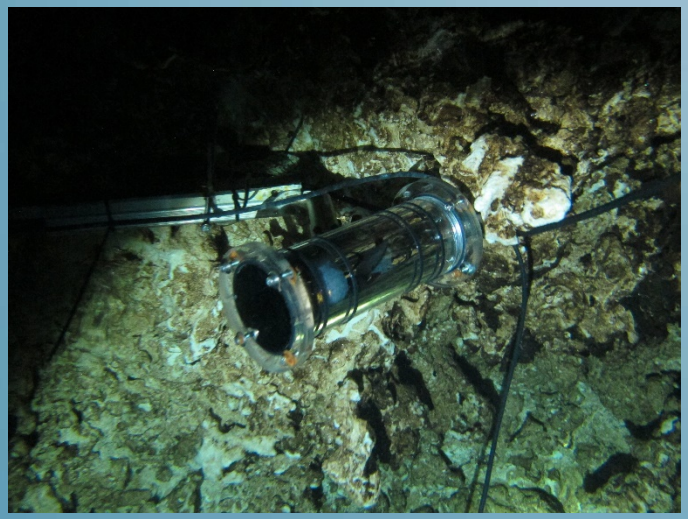
timer and record length have to be synchronized

Recording time: **2 minutes**
Recording interval: **1h 58 minutes**

CAMERA UNIT

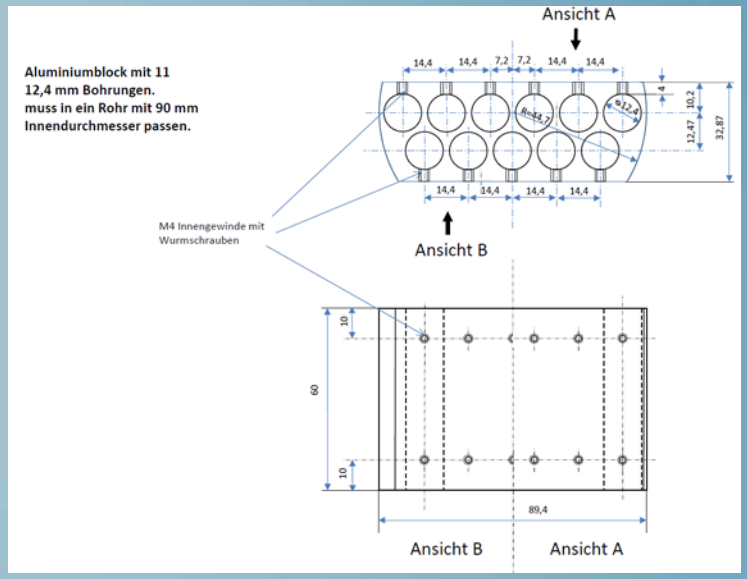
03/09/2016

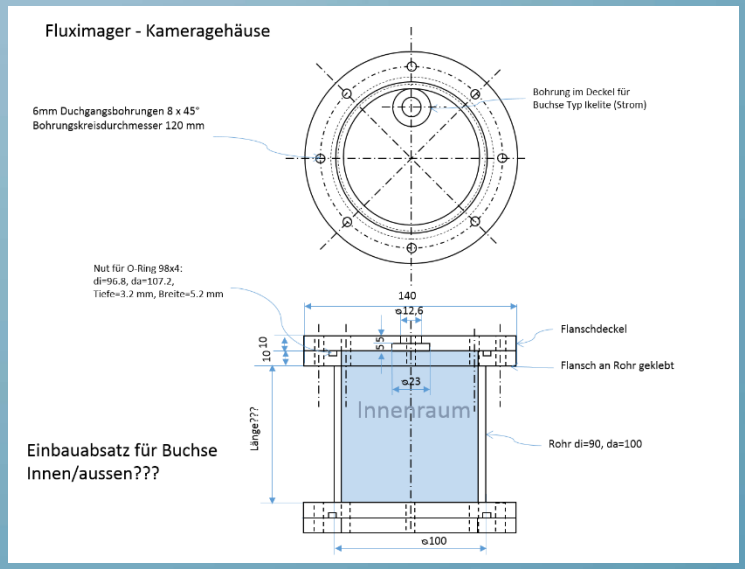




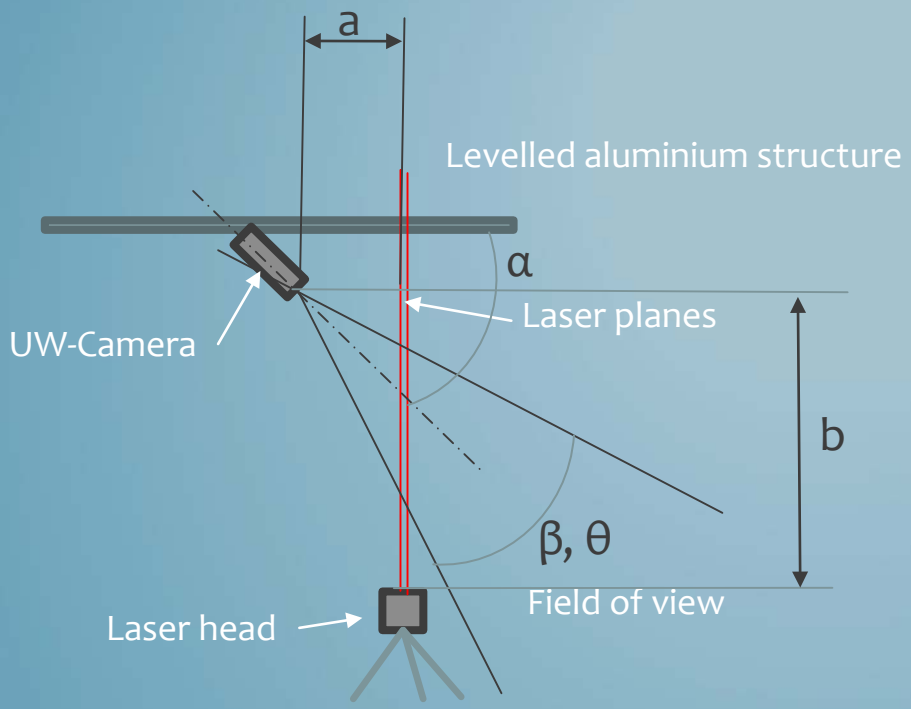
CCD-Sensor:	1/2" CCD Sensor
Pixel:	752(H) x 582(V) Pixel / CCIR
Typ:	CCIR
Resolution:	> 570 TVL (Center)
Sensitivity:	0.000005lx. F1.4 (Shutter: x256, AGC: HIGH, γ : 0.35)
Shutter:	Elek. – 1/50 ~ 1/100.000 sec. 1/60; 1/100 Sek; 1/50, 1/120 Sek.; 1/250, 1/500, 1/1000, 1/2000, 1/5000, 1/10000, 1/100000 sec.
AGC:	AN: LOW: 6-30dB / MID: 6-34.5dB / HIGH: 6-41dB; AUS: 6-41dB (1dB step)
Betriebstemperatur:	-10°C ~ + 50°C
Power:	DC+12V +/-10% mit 115 mA.
Size (HxBxT):	34 x 34 x 45,5 (zzgl. Stecker 13) mm.
Wight:	83 g.
Mount:	CS

LASER HEAD


Aluminiumblock mit 11
12,4 mm Bohrungen.
muss in ein Rohr mit 90 mm
Innendurchmesser passen.
Ansicht A
14,4
14,4
7,2
7,2
14,4
14,4
4
10,2
12,47
32,87
14,4
14,4
14,4
14,4
M4 Innengewinde mit
Wurmschrauben
Ansicht B
10
60
10
89,4
Ansicht B
Ansicht A


Fluximager - Kameragehäuse
6mm Duchgangsbohrungen 8 x 45°
Bohrungskreisdurchmesser 120 mm
Bohrung im Deckel für
Buchse Typ Ikelite (Strom)
Nut für O-Ring 98x4:
di=96.8, da=107.2,
Tiefe=3.2 mm, Breite=5.2 mm
140
⌀12,6
Flanschdeckel
10 10
5,5
Flansch an Rohr geklebt
⌀23
Innenraum
Länge???
Rohr di=90, da=100
Einbauabsatz für Buchse
Innen/aussen???
⌀100

CALIBRATION / MAPPING



Real co-ordinates (x,y) = (f(px, a,b, α, β, θ), f(py, a,b, α, β, θ))
px,py: pixel co-ordinates.

Realised as 2d-look up table with linear interpolation.

Maximum measurement area: trapez with base line 2m, top line 1m, height 1.5 m = 2.25 qm.

RAW DATA

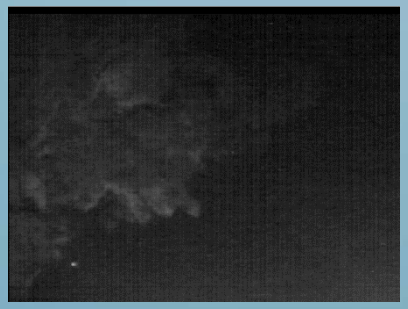
- Sample Screen shots ds=1.2 cm

t1=0.595

t2=1.786

t3=2.989

t4=4.481

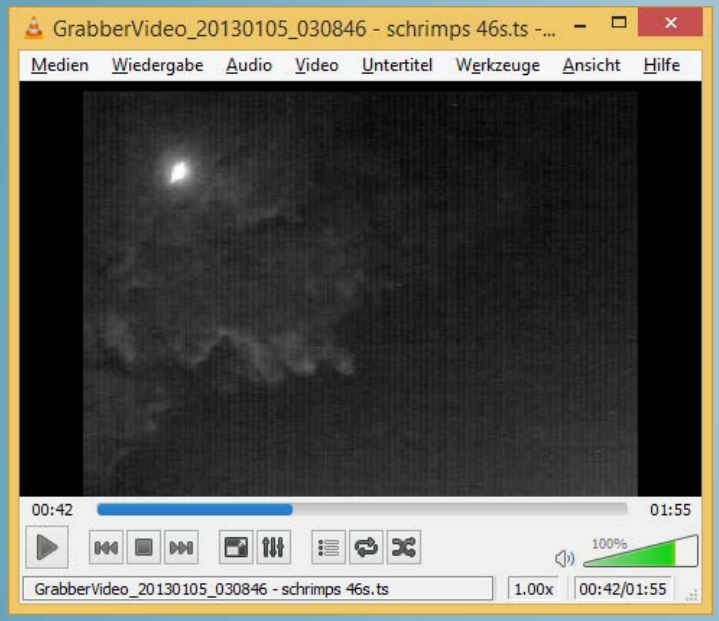


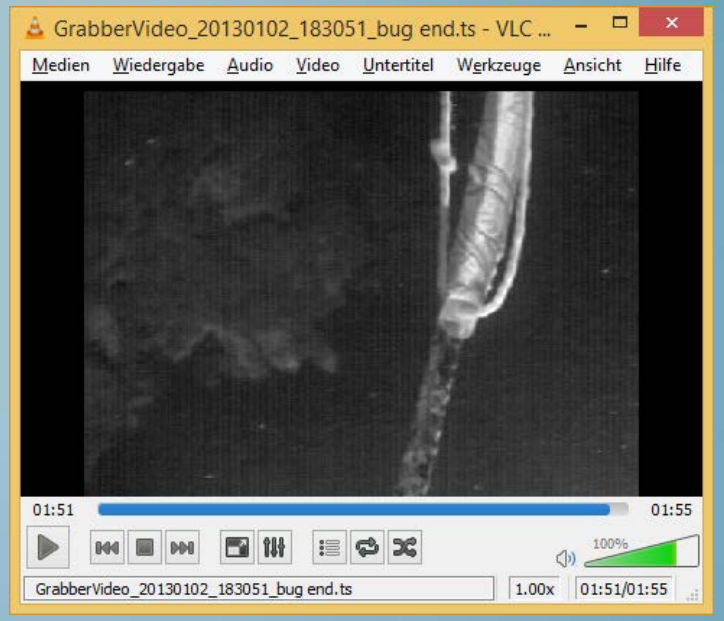
t5=5.955

t	dt	v	
0.595			
1.786	1.191	1.01	
2.989	1.203	1.00	
4.481	1.492	0.80	
5.955	1.474	0.81	
normal	mean v	0.91	cm/s

RAW DATA - RECORDS

INTERFERING PHENOMENA - STYGIOBIONTS





Right: Niphargus ictus (http://en.wikipedia.org/wiki/Niphargus)

Left: Proasellus cavaticus (http://www.karstforschung.at/H%F6hlenfauna.htm).

HOW TO TELL IT THE COMPUTER? - DATA PROCESSING

1) Frames of a record stored into 3d-array

2) Background reduction

3) Projection of 3d array along time axis (sum of frames) => identification of traces, calulation of mask.

4) Blanking data not identified as traces

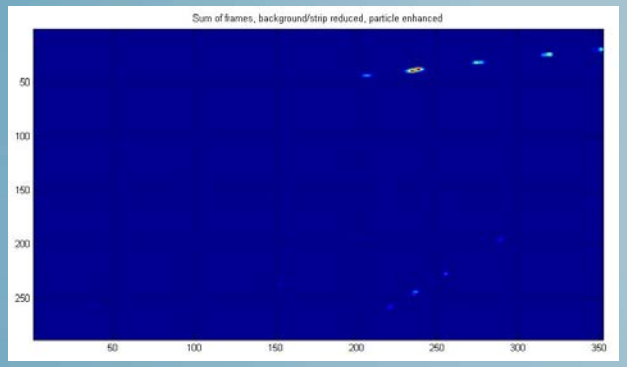
5) twofold projection of filtered traces along frame axis => peak series

6) Analysis of peak series => frame intervals => time intervals
=> normal velocity-component.

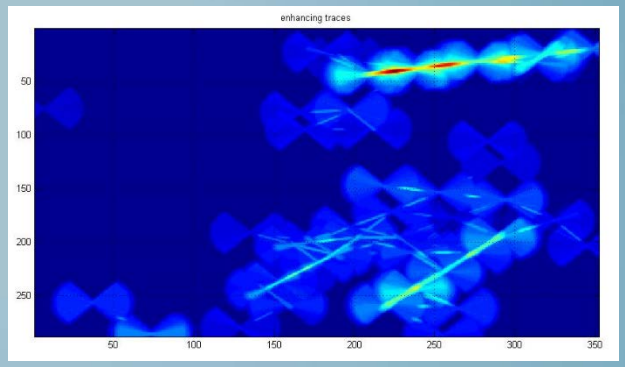
7) Done for several traces: spatial and temporal distribution of normal velocity component as input for flux calculation.

Data Processing at an example

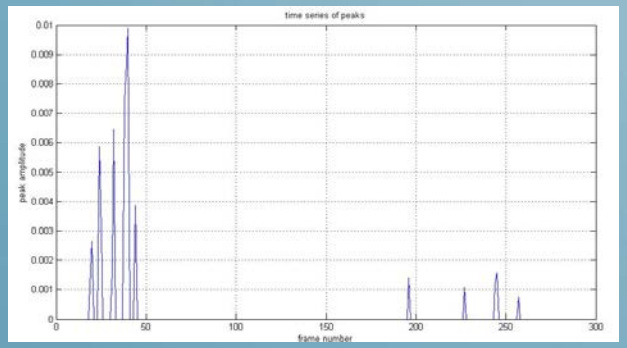
Particle enhancement



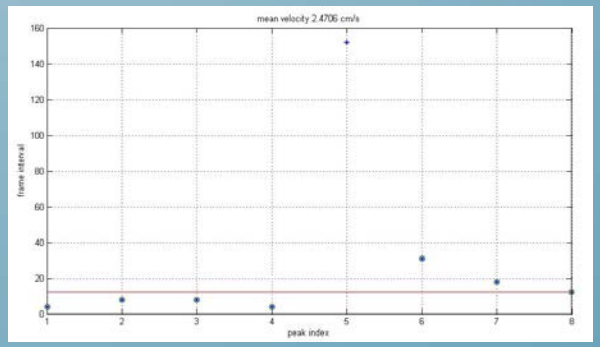
Searching traces



Finding peak series



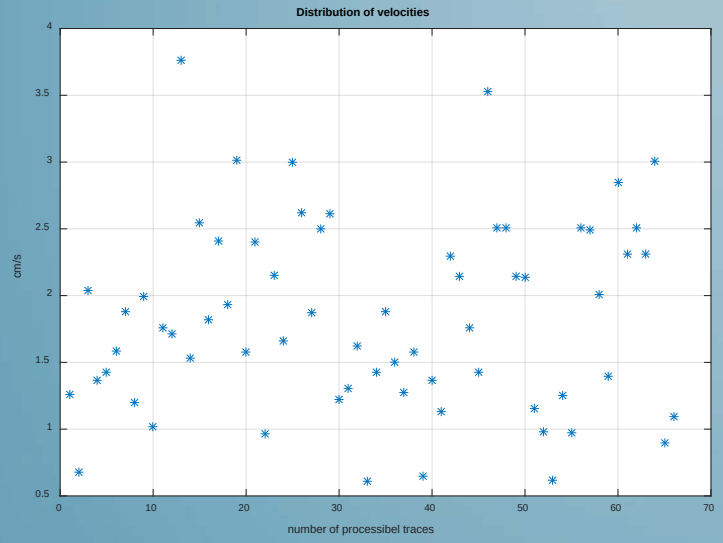
Deriving velocities

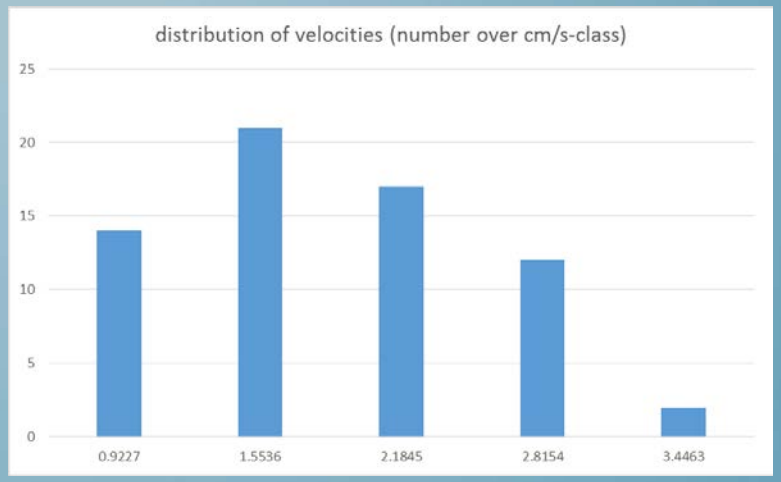


STATISTICS WITHIN ON RECORD

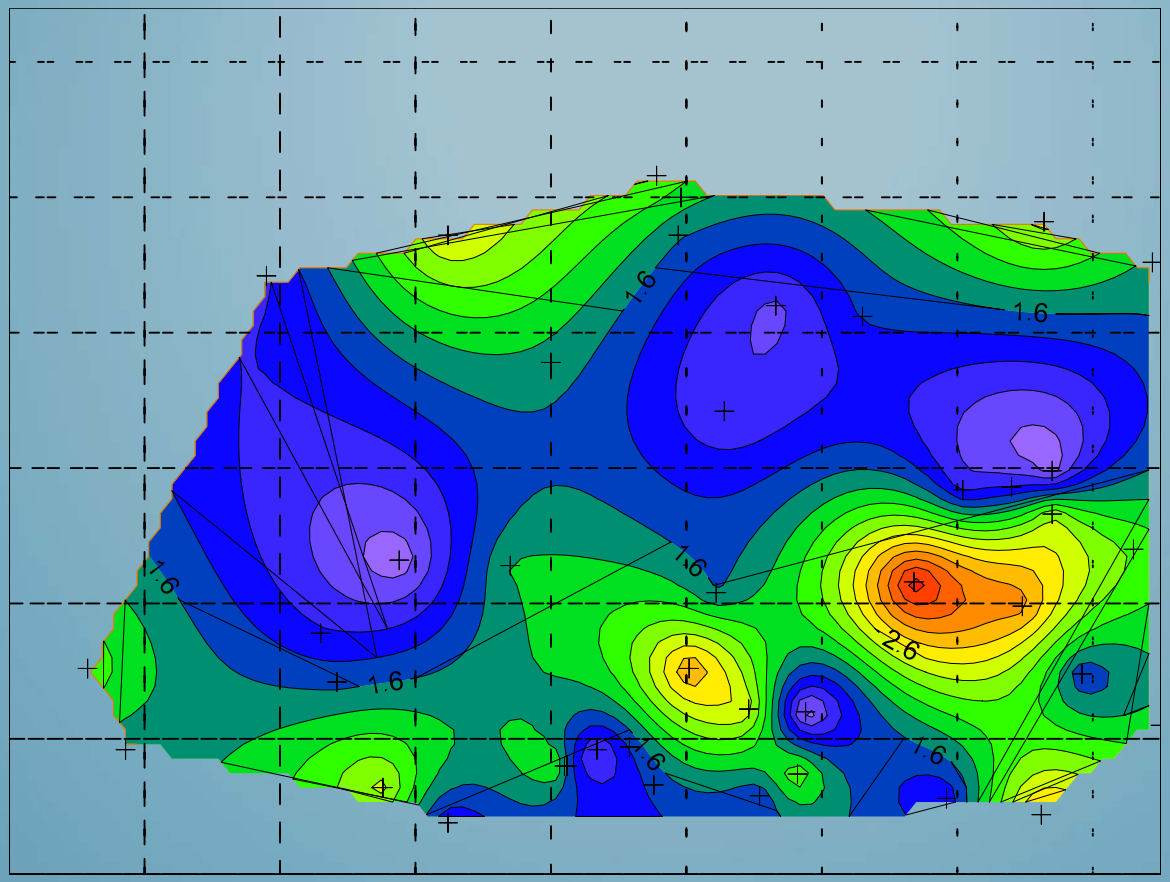
Example:
Record GrabberVideo_20130421_093724, 41 traces analysed
mean velocity: 1.8287 cm/s

Standard deviation: 0.7090 cm/s - due to turbulences!



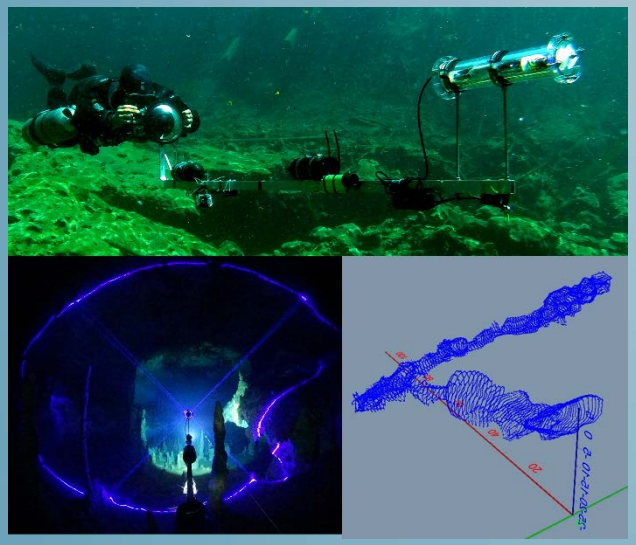


NORMAL VELOCITY DISTRIBUTION IN PIXEL DOMAIN

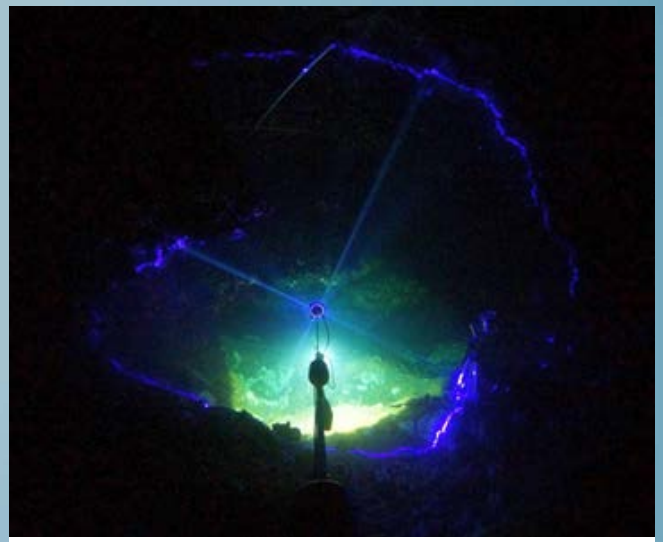


SUPPORTING METHOD FOR FLUX MEASURMENT: LASER SCAN OF TOTAL CROSS SECTION

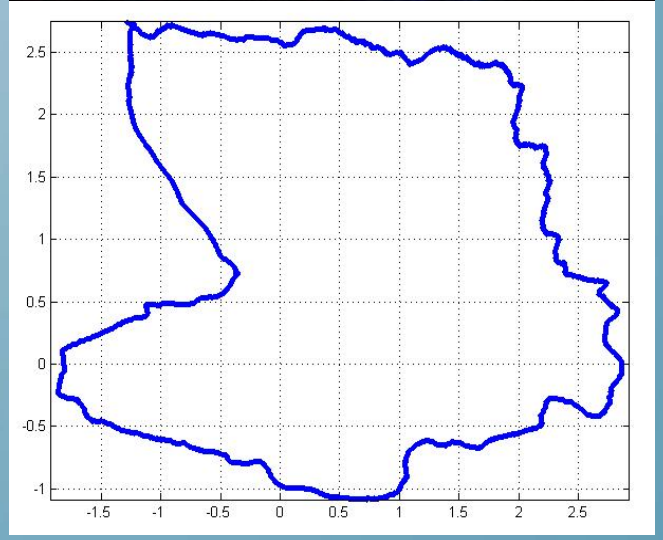
‚Cave Scanner‘



Laser scan image data



Mapped into true dimension



Area of total cross section: 11.625 m^3

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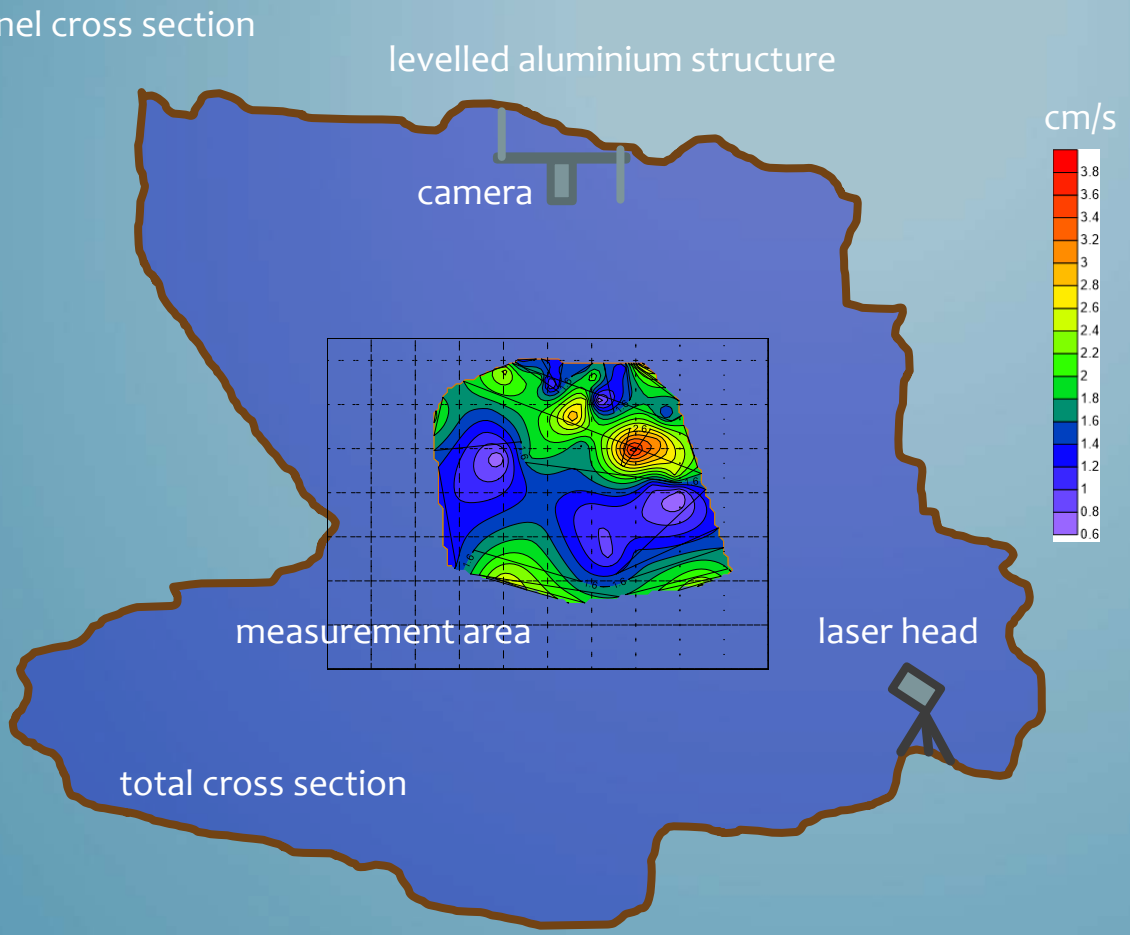
TRUE SCALE NORMAL VELOCITY FIELD AND FLUX ESTIMATION



Planar Area:
Positive Planar Area: 11763.3 cm^2
or 1.176 m^2

Flux through Area:
Total Volumes by: **cm^3/s**

Trapezoidal Rule: 20160.1
Simpson's Rule: 20133.8
Simpson's 3/8 Rule: 20159.1

Flux: **20.15 liters/s**

(extraploated to whole cross section up to 200l/s)

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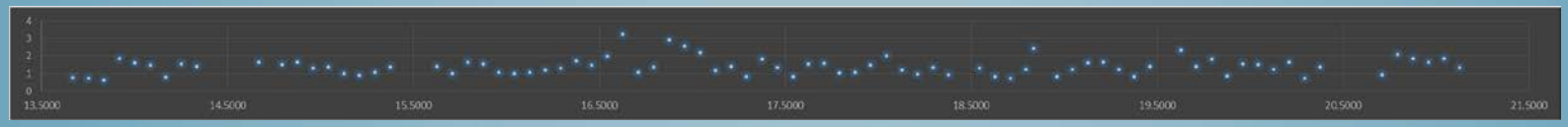
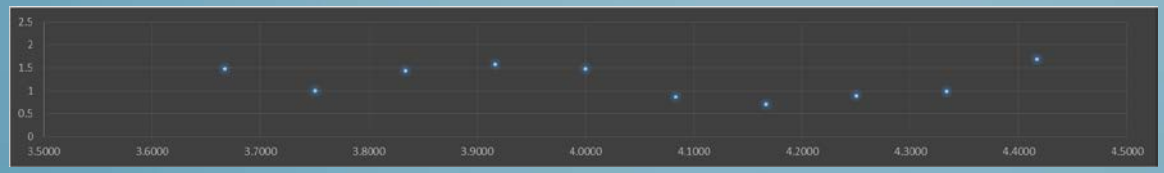
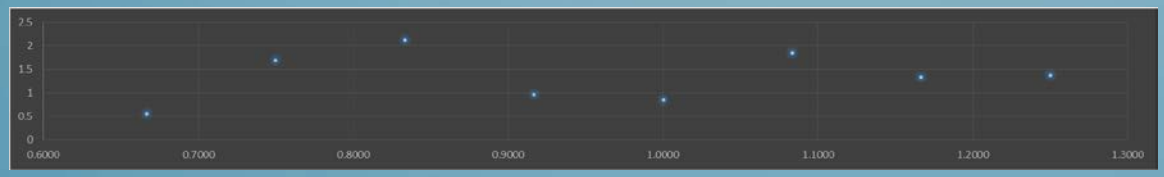
RESULTS –SHORT TERM SERIES SERIES

Normal component of velocity over day/time
cm/s over day start 26.05.2015 time interval: 2 hours.



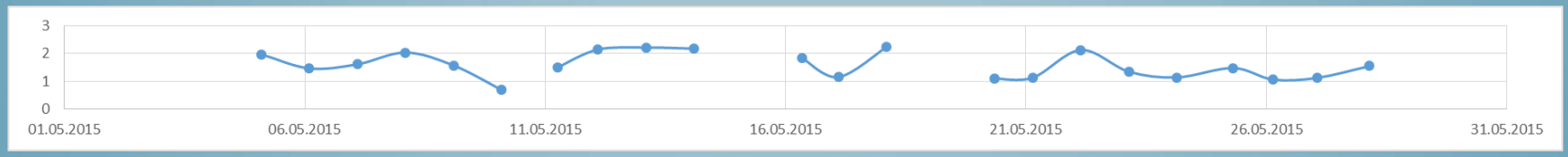
Short term variations - detail

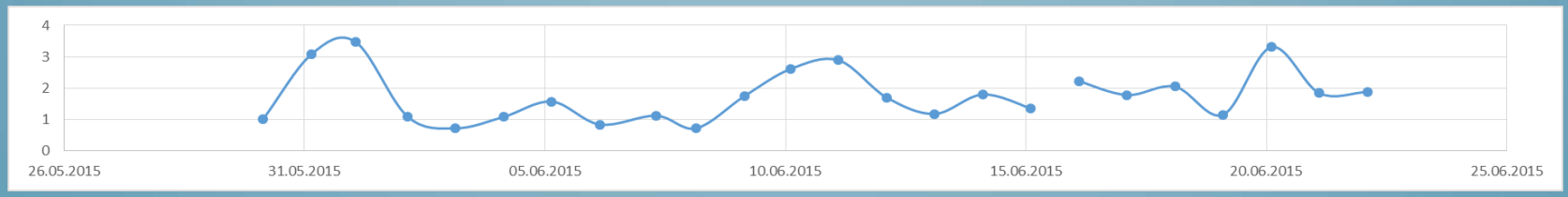




RESULTS –SHORT TERM SERIES SERIES

Normal component of velocity over day/time
cm/s over day time interval: 1 day





CONCLUSION

- Slow turbulences imagable - complex temporal/spatial velocity field
- Improved flux estimation
- Variations with periods T < 0.5 days, amplitude 0.25-0.5 mm/s
- Superior resolution of low velocities
- Clear water/ darkness required

Next Steps:

- Improving full automatic image processing
- Data reduction on site
- Extension to wider area
- Artificial particle generation (electrolysis - bubbles)
- Full autonomous system (under water battery)

Geological Survey of Austria

Gracias

03/09/2016

Amigos de Sian Ka'an

to Leopoldo Pellon (divings unlimited),
Jaime, Alvaro, Bil Phillips (speleotech.com),
and Toby, Sr. Nebi (land owner),
Axa Maqueda Estrada , Martin Hendricks,
Jim Coke, Simon Richards,

- and to the audience

Arnulf Schiller, Alejandro Lopez Tamayo

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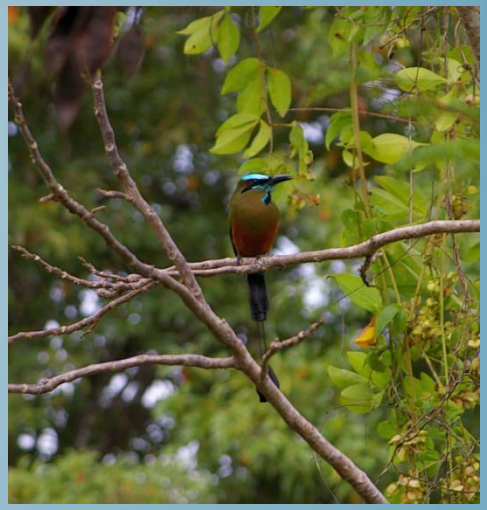
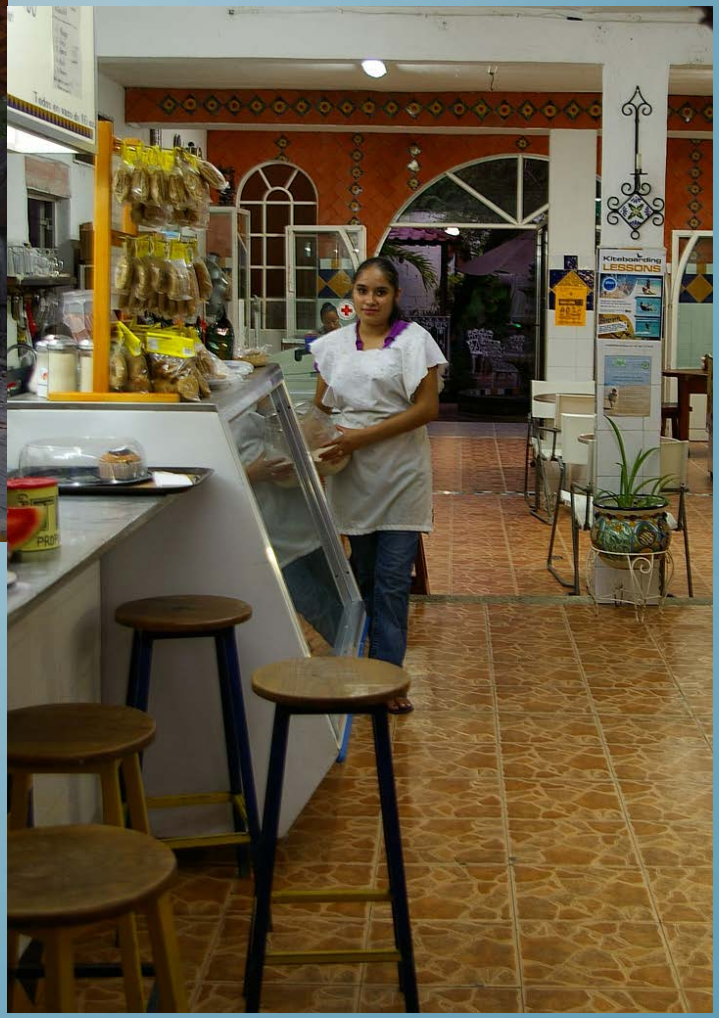
FWF




Restaurant y Cocteleria
SEA FOOD
Las Brasas
Bienvenidos...
ACCESORIOS
DE BICIS Y
DE MOTOS
Jugos!!


Kiteboarding
LESSONS