Session HS2.3.1

Observing hydrological processes: recent advancements in surface flow monitoring through image analysis

Flavia Tauro and Salvatore Grimaldi
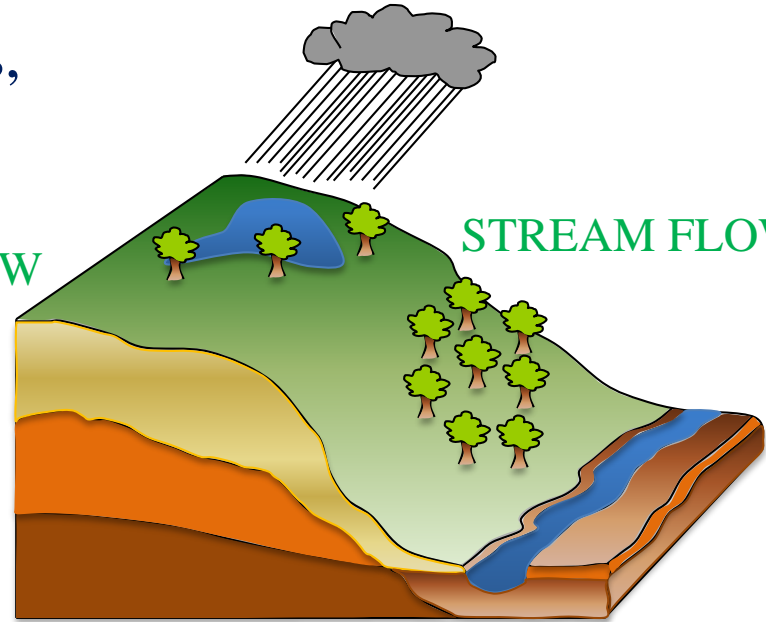
Surface hydrology

Surface processes control

- flood hydrology,

- rainfall-runoff relationships,

- landscape evolution,

- …

OVERLAND FLOW

STREAM FLOW

CHANNEL FLOW

Surface flow observations: issue 1

- ## Multiscale and heterogeneity

RILLS   STREAMS   RIVERS

rivers:
- high regime
- vegetation
- large cross-section and depths

hillslope rills:
- from a few to several cm
- turbidity
- vegetation

streams:
- sediments
- high regime
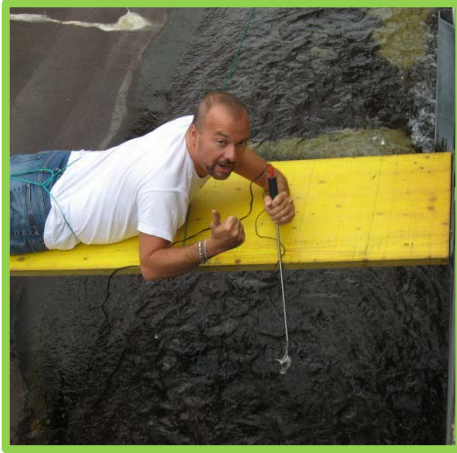- shallow depths
- irregular beds
- reflections
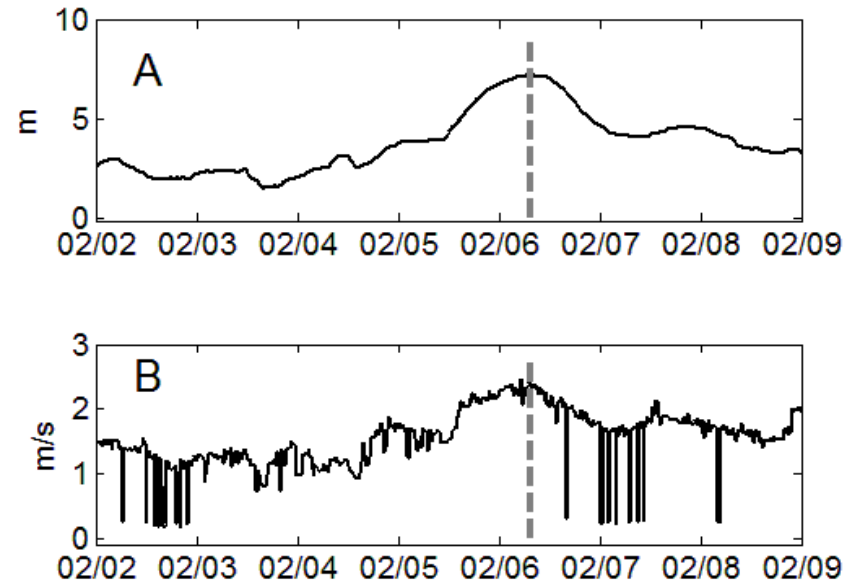
Surface flow observations: issue 2

- Accessibility for ground-based measurements
  – Sensors deployment
  – Access for operators

- What about floods?

Surface flow observations: issue 3

- Fastly evolving dynamics
  - Example: moderate flood in the Tiber river

Traditional stream flow measurement systems

- Pointwise observations at selected cross-sections
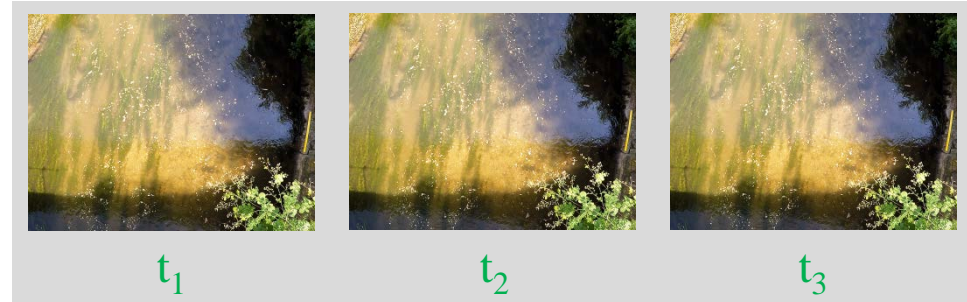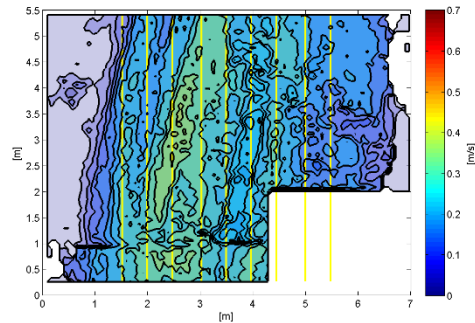- Often invasive measurements

ultrasonic meters
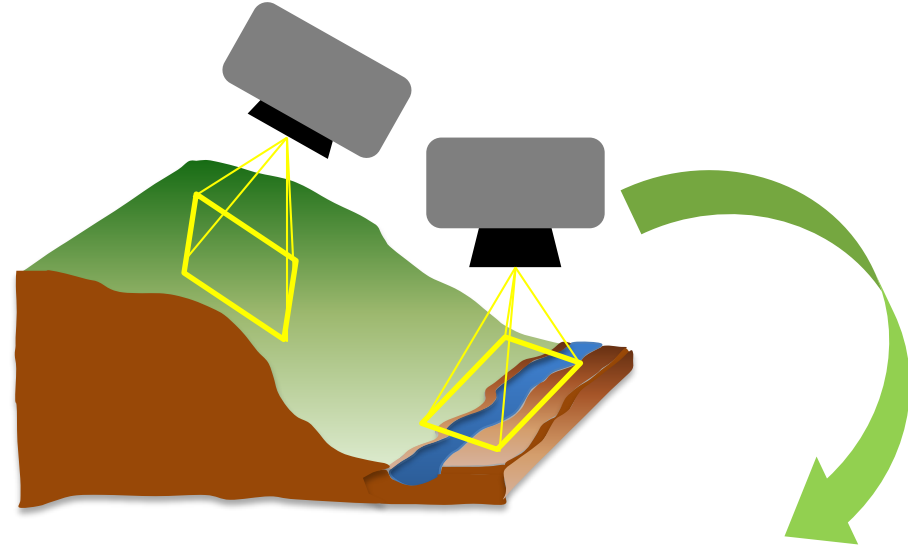
portable current meters

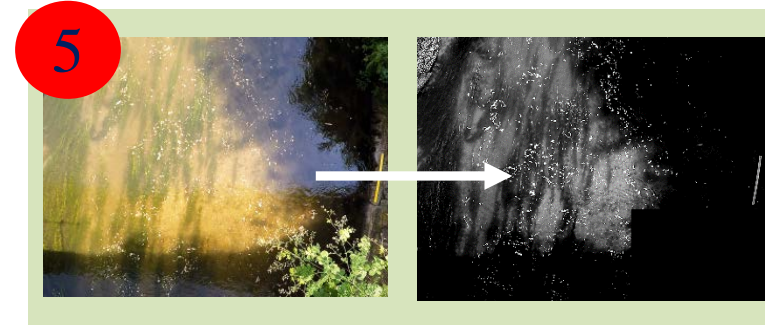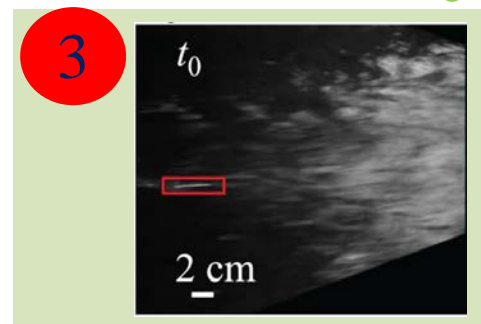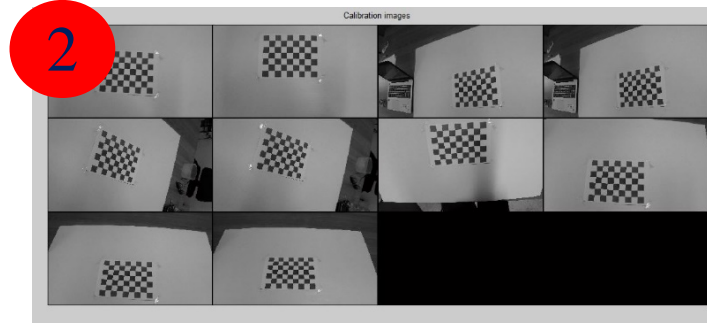radar systems

acoustic doppler current profilers

Imagery

Image-based observations are

- – noninvasive,
- – distributed,
- – at high temporal resolution,
- – not constrained by the scale

t_1 t_2 t_3

Imagery: from raw images to usable data
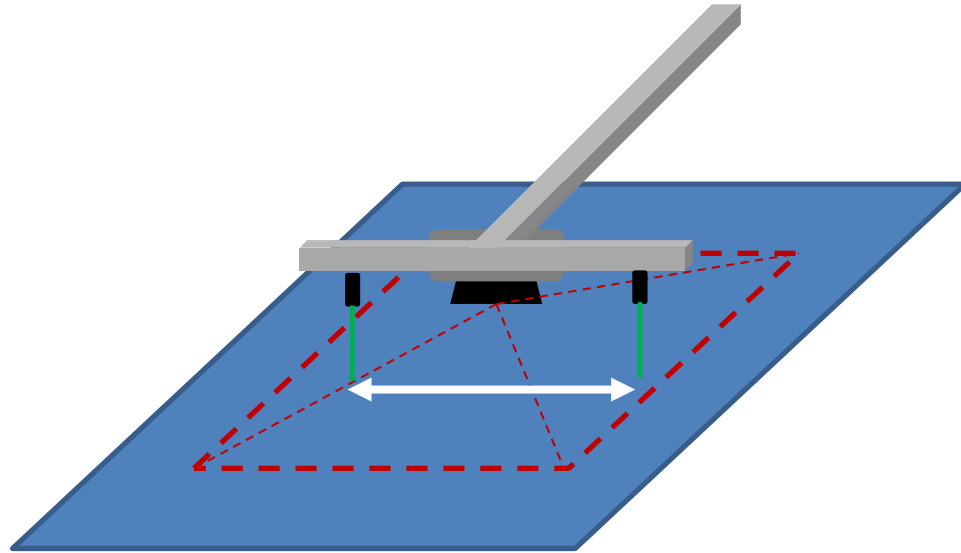

DATA

1. Frame extraction
2. Camera calibration
3. Image orthorectification
4. Frame calibration
5. Frame enhancement

Imagery: from raw images to usable data

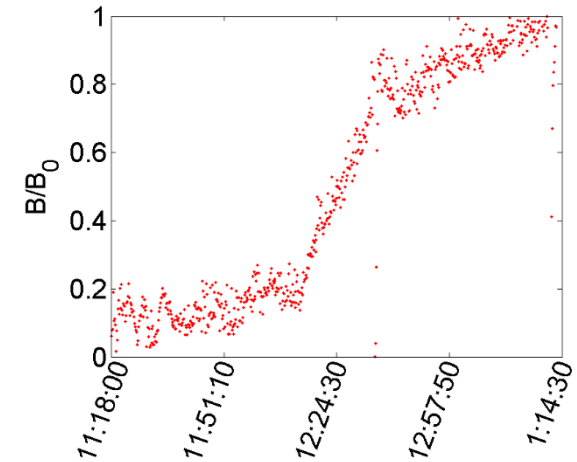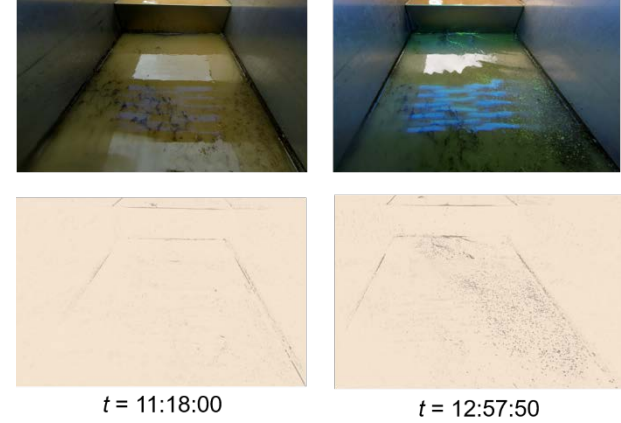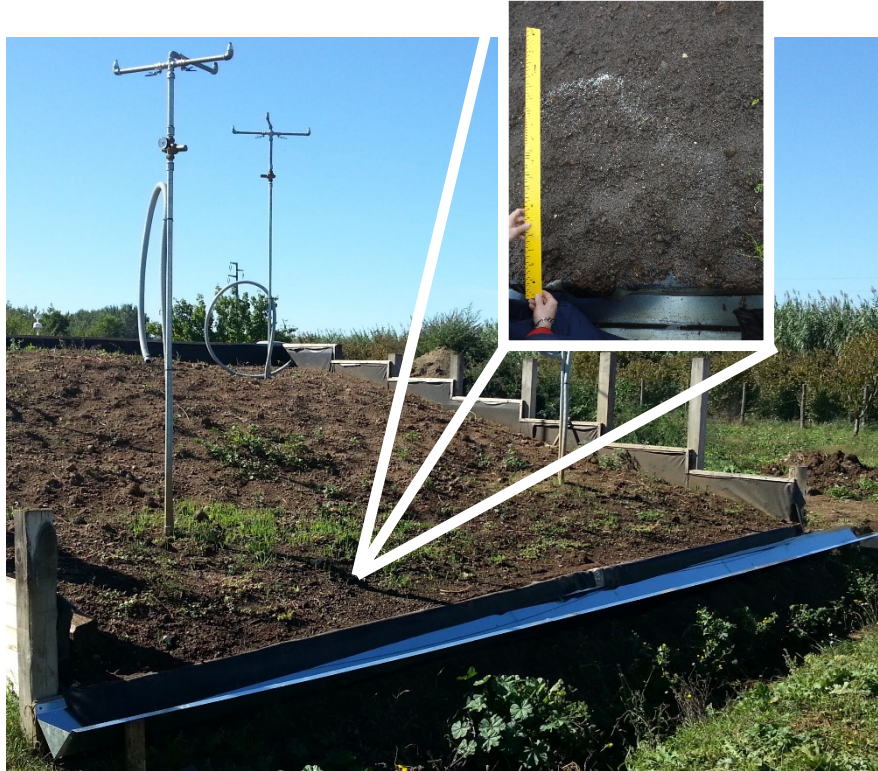## Simplifying image orthorectification and calibration

Orthorectification:

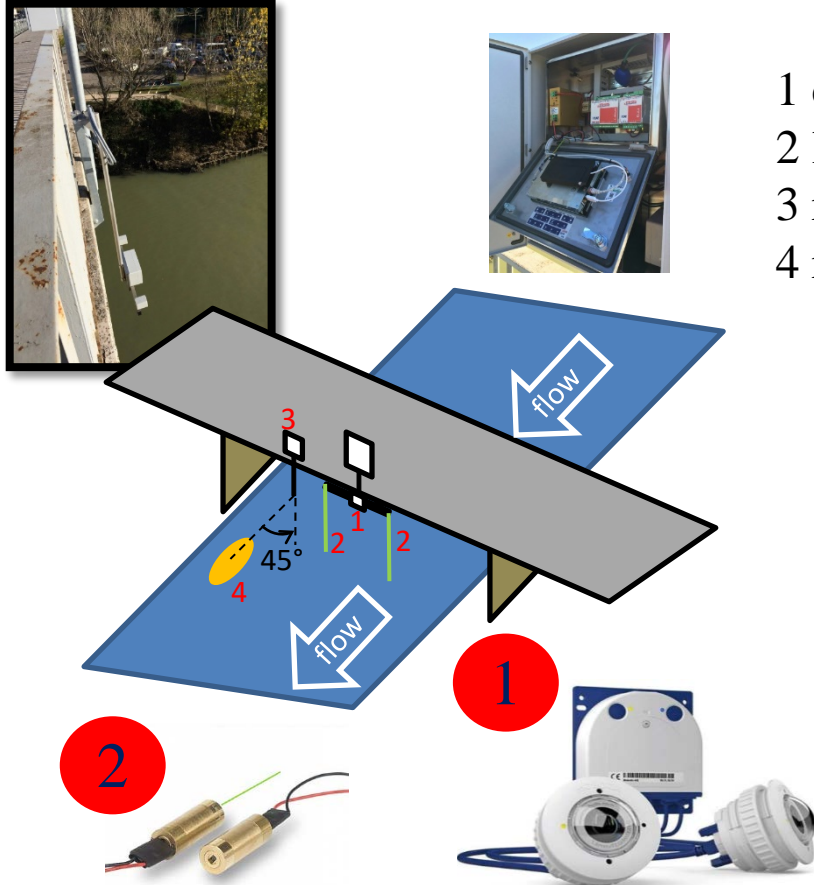Camera orthogonal to water surface

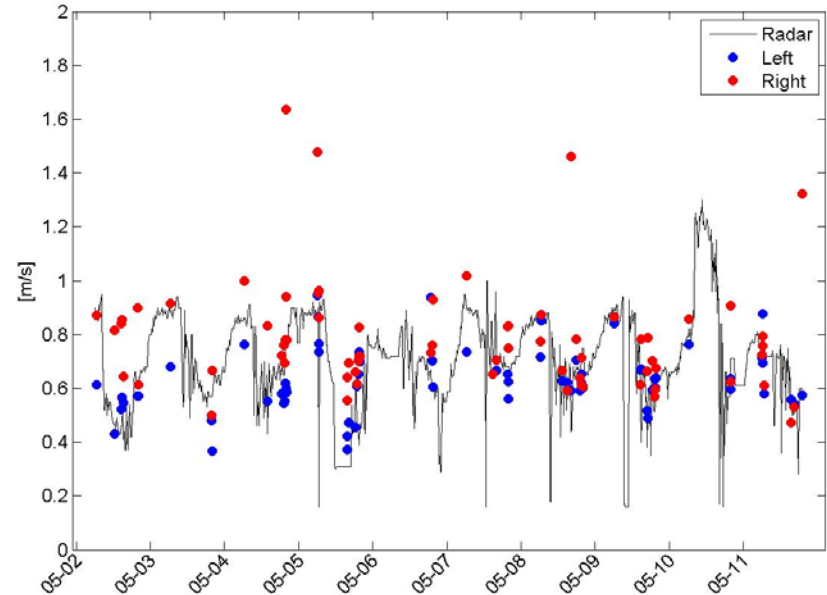Remote calibration:

System of lasers at known distance

Overland flow: addressing multiscale
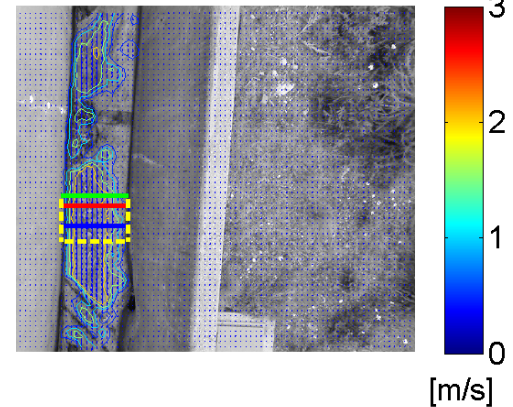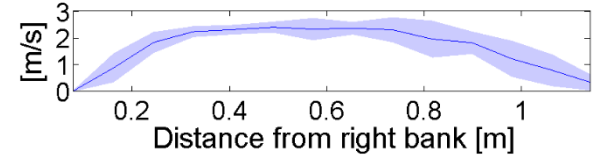
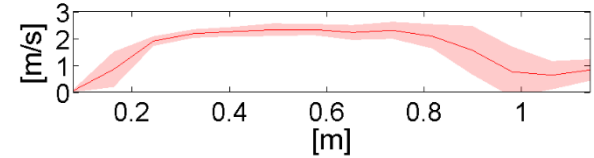- Imagery and high visibility tracers

$t = 11{:}18{:}00$ $t = 12{:}57{:}50$

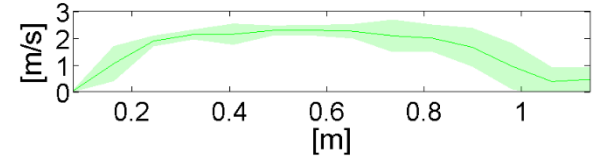# Permanent station: addressing fast dynamics

1 camera
2 lasers
3 radar
4 radar's trace on water surface

Unmanned Aerial Systems: addressing accessibility
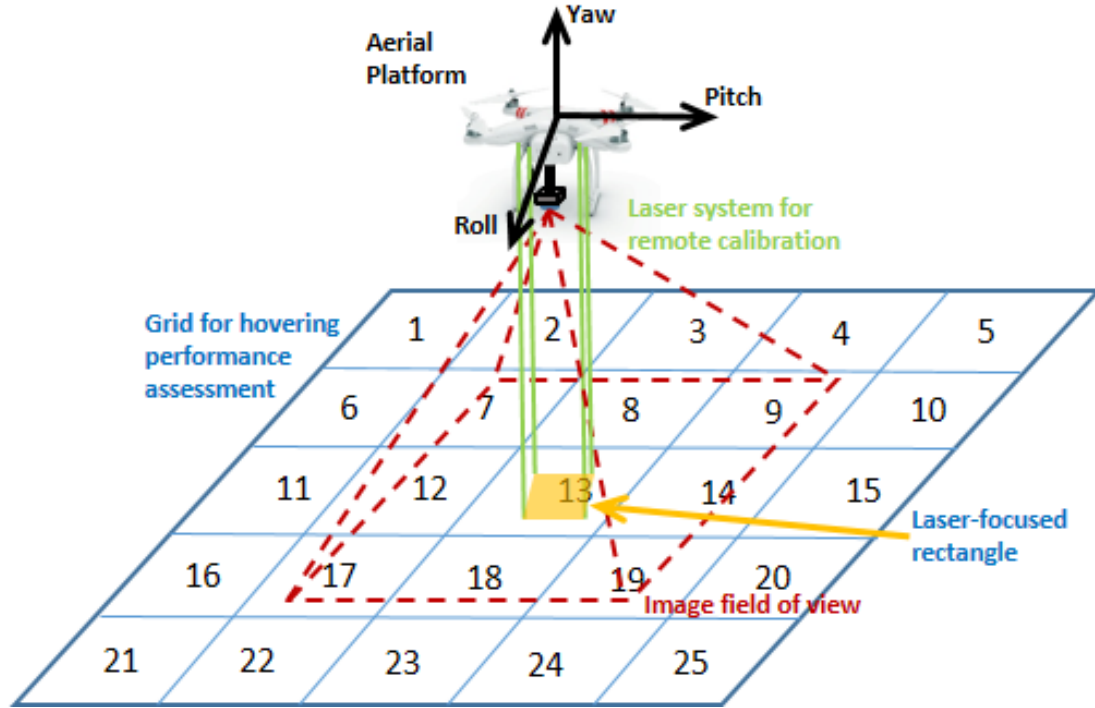
Establishing new methodology to inform process knowledge

- Example: surface velocity from images
- Two major image-based procedures:

Large Scale Particle Image Velocimetry

frame 1 frame 2
grid
interrogation area
search area
velocity vector
discrete velocity map
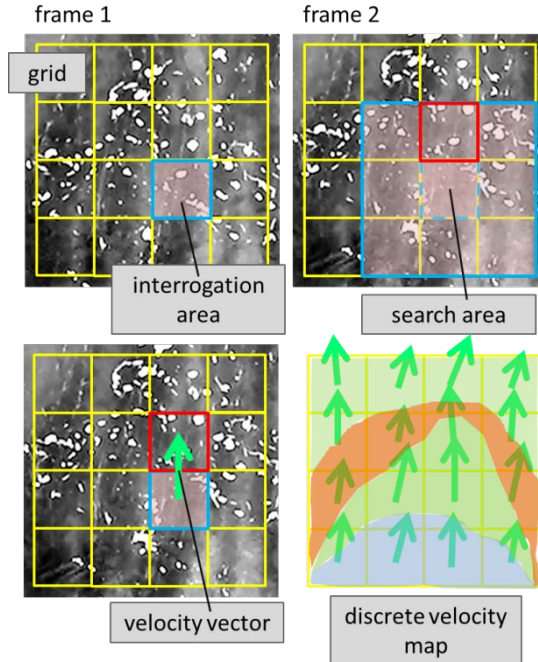
Particle Tracking Velocimetry

frame 1 frame 2
particle tracking
particle identification
velocity vector
trajectories

Establishing new methodology to inform process knowledge
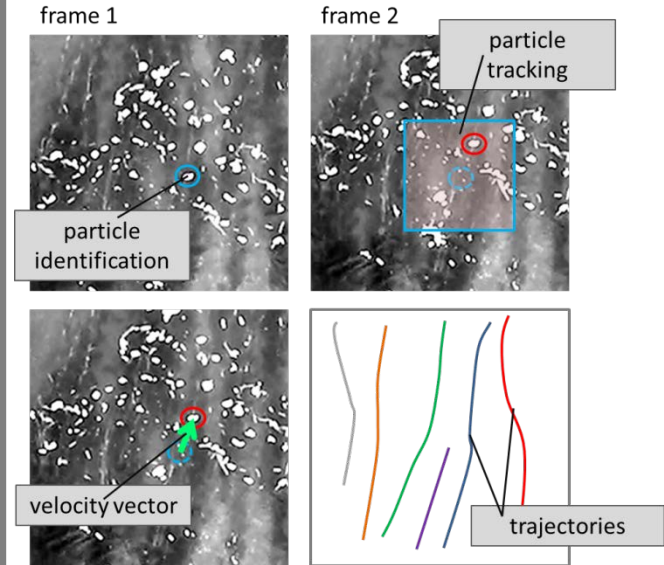
- Case study on the Brenta River
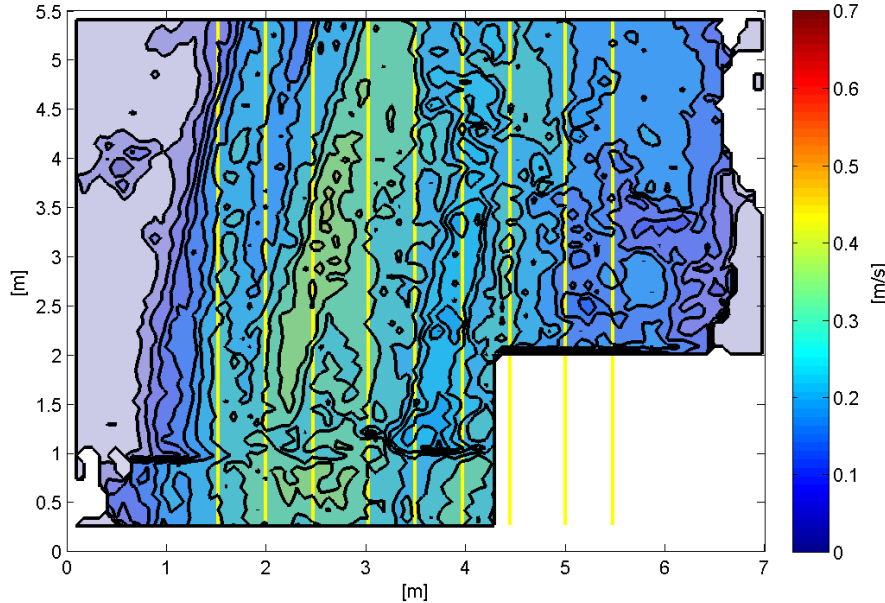
LSPIV:
- often underestimates velocities
- difficult to assign uncertainty

PTV:
- based on individually tracked floaters
- can we assign data uncertainty?

HS2.3.1 Observing stream flow with images

- PTV: filtering realistic trajectories

Comparison among LSPIV, PTV, and estimations from a current meter
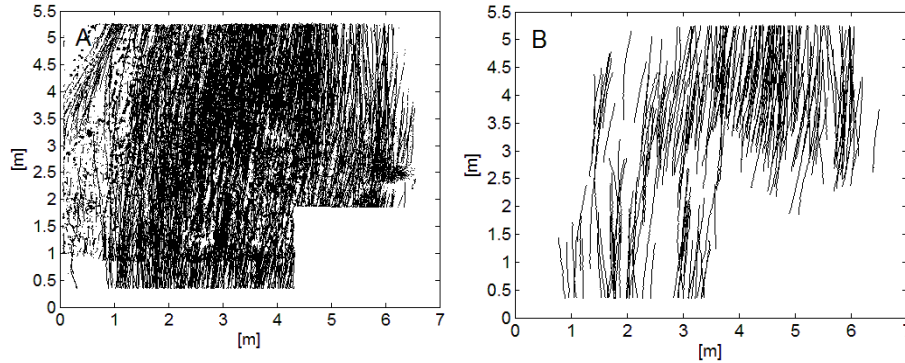
- More accurate velocity estimations

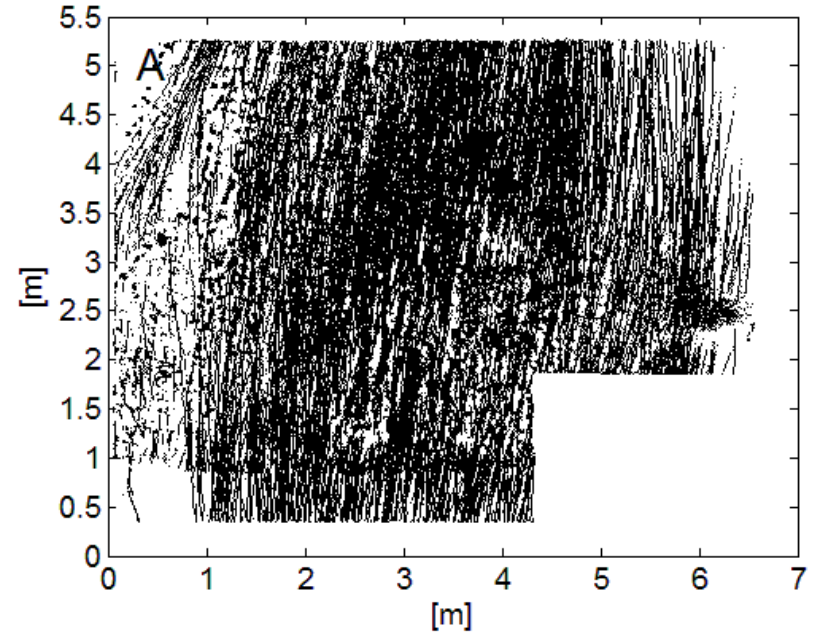- Accuracy can be better controlled
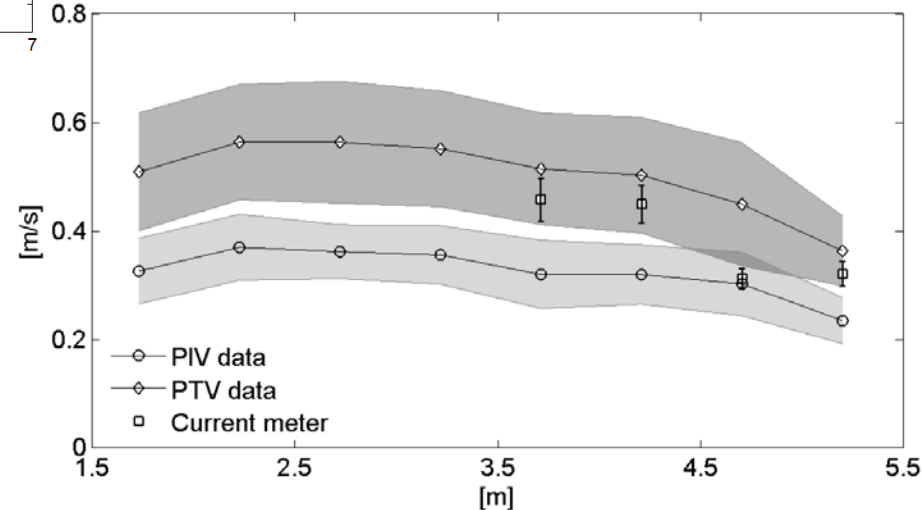
Conclusions

- Images afford:
  - Distributed
  - Potentially continuous
  - Remote

  surface flow measurements

- Establishing a new methodology requires:
  - Thorough comparison with traditional techniques
  - Assigning data accuracy

References

- Petroselli A., Tauro F.: "Cape Fear: monitoring basic hydrological processes in an outdoor hillslope plot", Environmental Monitoring and Assessment, 189(3), 132, 2017.
- Tauro F., Grimaldi S.: "Ice dices for monitoring stream surface velocity", Journal of Hydro-environment Research, 14, 143–149, 2017.
- Tauro F., Salvatori S.: "Surface flows from images: ten days of observations from the Tiber River gauge-cam station", Hydrology Research, nh2016302, 2016.
- Tauro F., Porfiri M., Grimaldi S.: "Surface flow measurements from drones", Journal of Hydrology, 540, 240–245, 2016.
- Tauro F., Petroselli A., Porfiri M., Giandomenico L., Bernardi G., Mele F., Spina D., Grimaldi S.: "A novel permanent gauge-cam station for surface flow observations on the Tiber river", Geoscientific Instrumentation, Methods and Data Systems, 5(1), 241–251, 2016.
- Tauro F., Olivieri G., Petroselli A., Porfiri M., Grimaldi S.: "Flow monitoring with a camera: A case study on a flood event in the Tiber River", Environmental Monitoring and Assessment, 188(2), 118, 2016.
- Tauro F., Petroselli A., Arcangeletti E.: "Assessment of drone-based surface flow observations", Hydrological Processes, 30(7), 1114–1130, 2016.
- Tauro F., Porfiri M., Grimaldi S.: "Orienting the camera and firing lasers to enhance large scale particle image velocimetry for stream flow monitoring", Water Resources Research, 50(9), 7470–7483, 2014.

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Measurements & Observations in the XXI Century (IAHS)
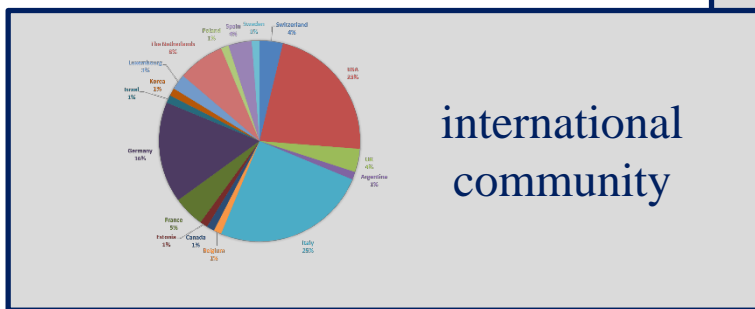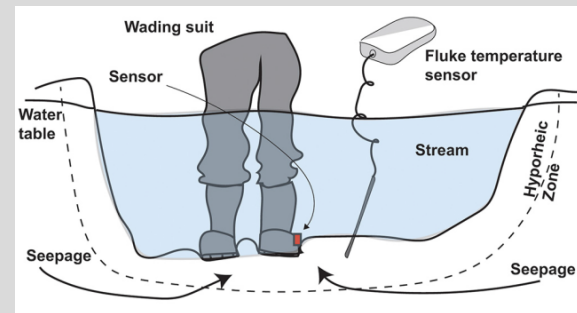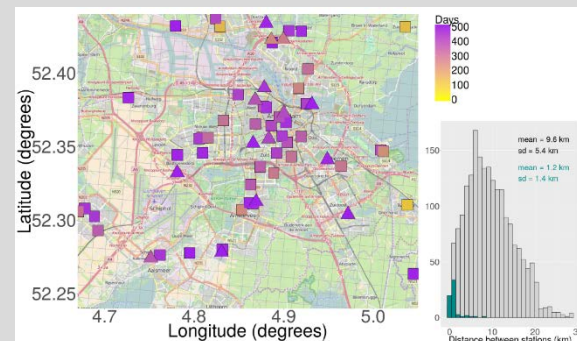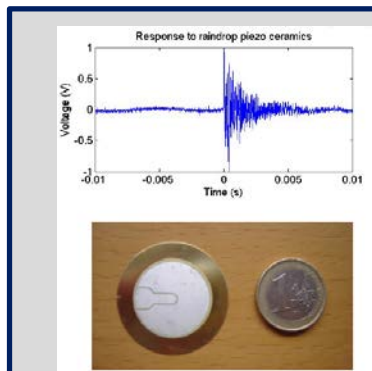
dedicated website

international community

new ideas

Thanks for listening!

Thanks for listening!

Monitoraggio Intelligente per Infrastrutture Sicure

POR FESR 2014-2020 - ASSE 1 - AZIONE 1.2.2

Obiettivo generale: realizzare un sistema integrato di monitoraggio e diagnostica applicabile a alvei, argini e sponde ed infrastrutture viarie che, utilizzando tecnologie oggi disponibili, ne incrementino la sicurezza consentendo interventi tempestivi.

Durata: 1.04.2016 - 31.03.2018

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