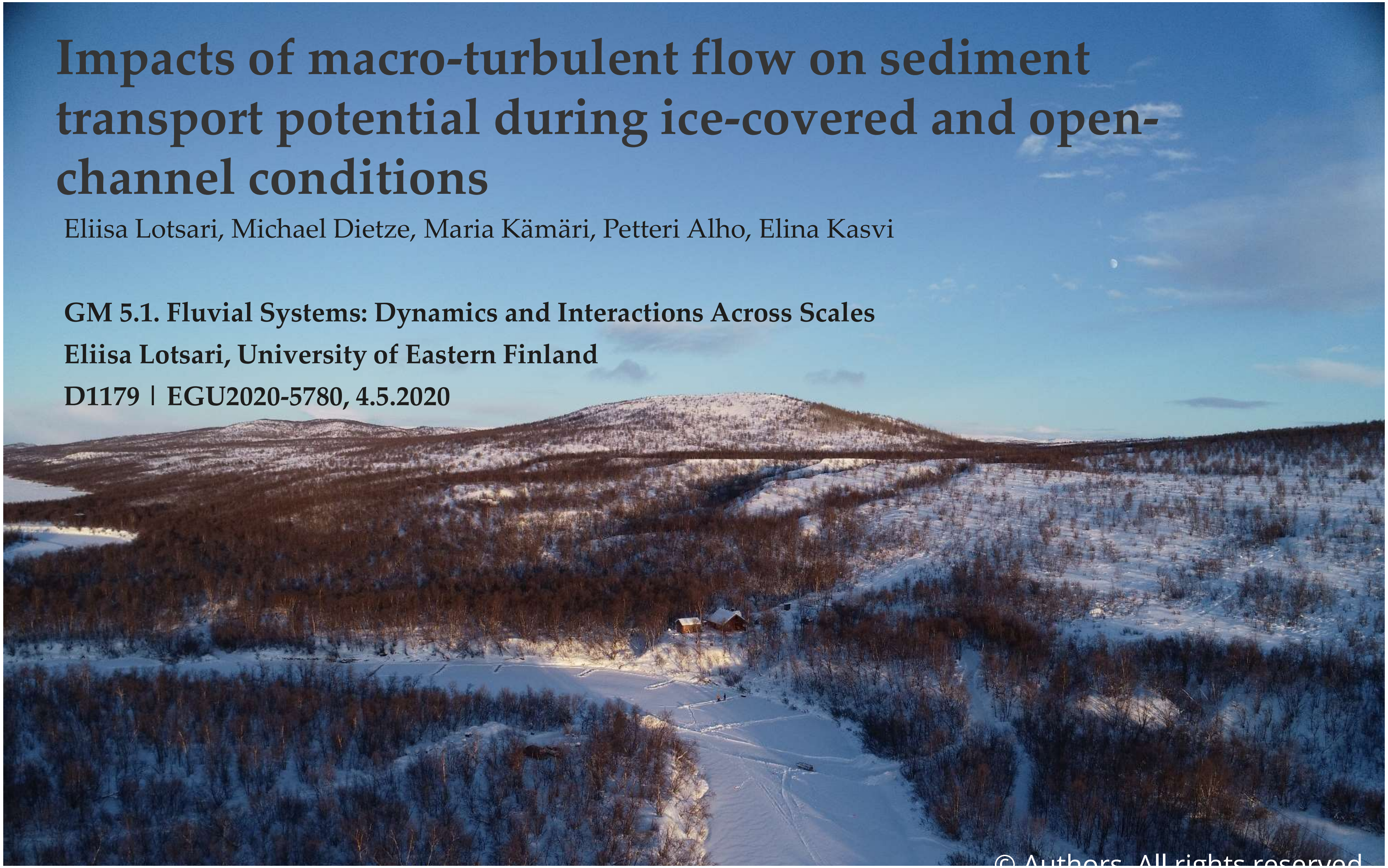
Impacts of macro-turbulent flow on sediment transport potential during ice-covered and open-channel conditions

Eliisa Lotsari, Michael Dietze, Maria Kämäri, Petteri Alho, Elina Kasvi

GM 5.1. Fluvial Systems: Dynamics and Interactions Across Scales

Eliisa Lotsari, University of Eastern Finland

D1179 | EGU2020-5780, 4.5.2020



Author affiliations
(full paper to be submitted in 2020)

- Eliisa Lotsari [1, 2], Michael Dietze[3], Maria Kämäri [4], Petteri Alho [2,5], Elina Kasvi [6, 2]
- [1]Department of Geographical and Historical Studies, University of Eastern Finland, Yliopistokatu 2, P.O. Box 111, FI-80101, Joensuu, Finland. eliisa.lotsari@uef.fi
- [2] Department of Geography and Geology, University of Turku, FI-20014 Turun yliopisto, Turku, Finland
- [3] Section 4.6 Geomorphology, German Research Centre for Geosciences GFZ Potsdam, D-14473 Potsdam, Germany
- [4]Finnish Environment Institute, Latokartanonkaari 11, FI-00790 Helsinki, Finland. maria.kamari@ymparisto.fi
- [5]Finnish Geospatial Research Institute, National Land Survey of Finland, Geodeetinrinne 2, FI-02430, Masala, Finland. mipeal@utu.fi
- [6] Turku University of Applied Sciences, Joukahaisenkatu 3, FI-20520, Turku, Finland. elina.kasvi@turkuamk.fi

Background

- Macro-turbulent flows during both open-channel and ice-covered flow conditions, and their impacts on the total sediment transport, have not been studied widely in northern seasonally frozen rivers.

- Thus, for understanding their impacts on the sediment transport, it is needed to detect these macro-turbulent flow structures from a variety of cold region rivers, from multiple years, and also from a variety of different flow magnitude conditions.

- The pulses of high flow velocities related to these macro-turbulent structures may be important for determining the seasonal total sediment amount transported to oceans.

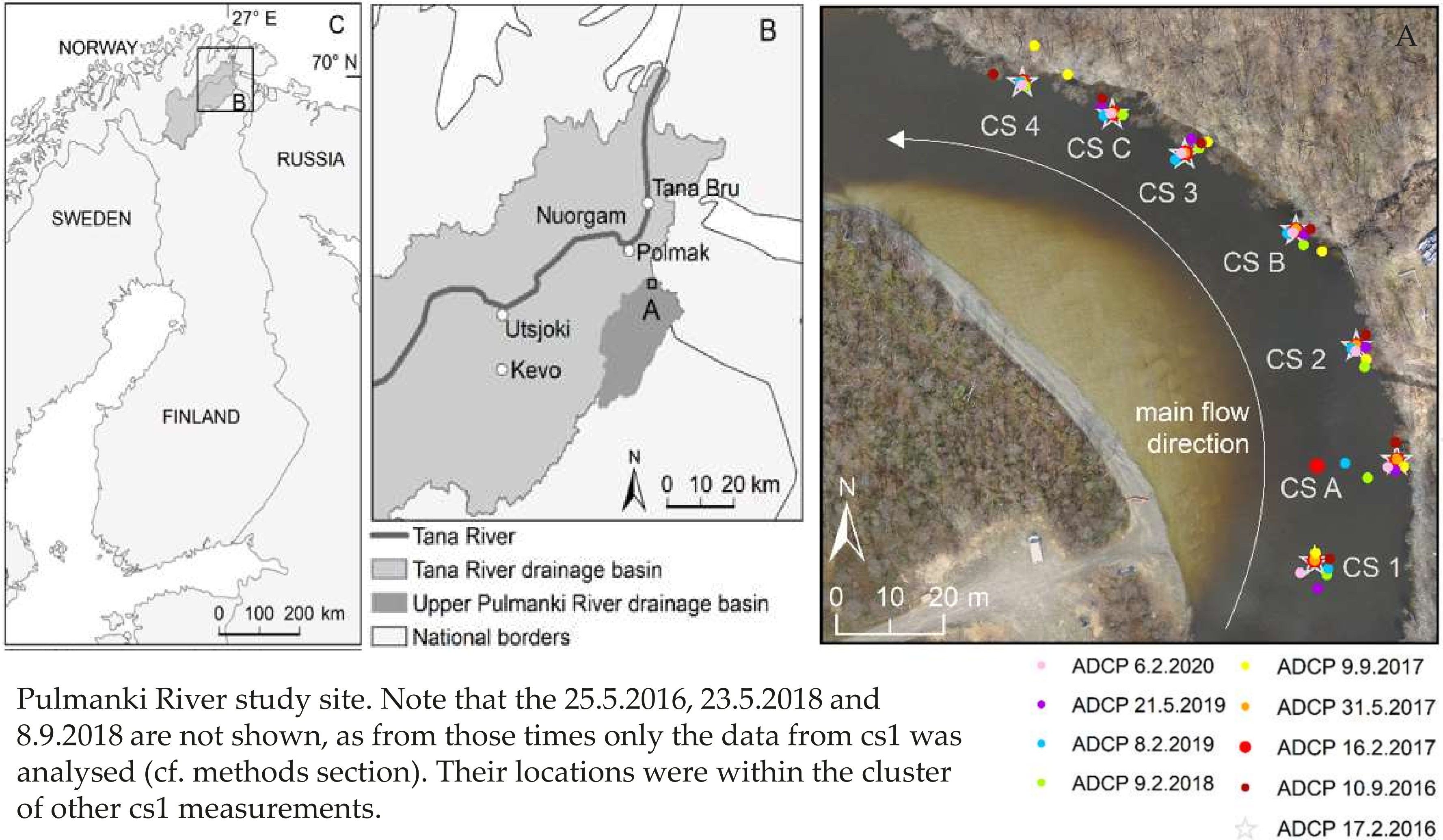
Therefore, the aims are

- 1) to detect and compare the marcoturbulent flow (flow pulsations) both at open-channel and ice-covered flow conditions.
- 2) Within the meander bend, the macro-turbulent flow will be compared between inlet, apex and outlet sections of the meander bend.
- 3) The magnitudes of the near-bed layer flow will be analysed throughout the meander bend to detect the effects of macroturbulence on bedload transport.

Methods

- The analyses are based on 5–10 minutes long Acoustic Doppler Current Profiler (ADCP) measurements from seven high velocity locations along a meander bend.

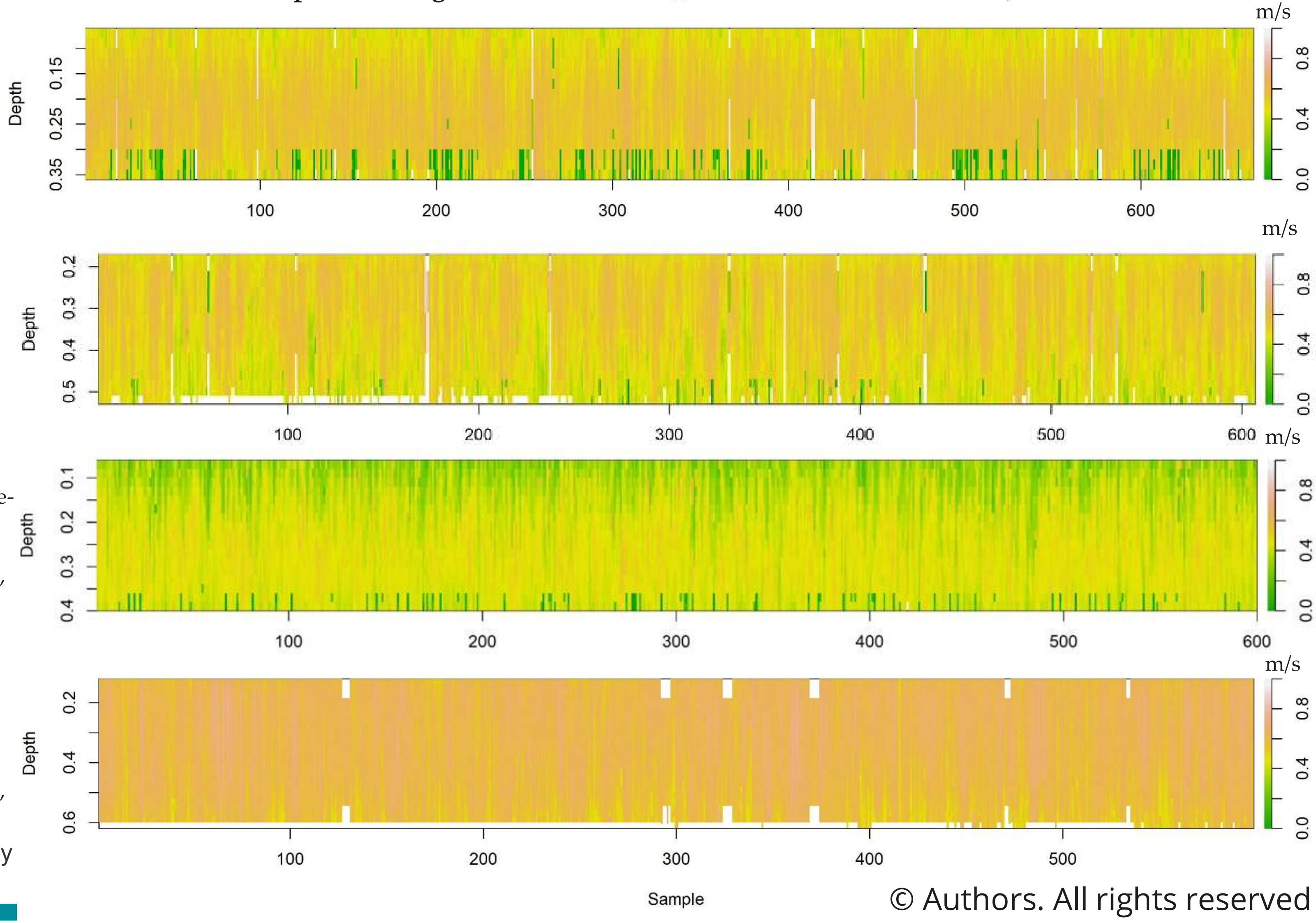
- The measurements have been done in February (winter: ice-covered low flow), May (spring: open-channel higher flow) and September (autumn: open-channel low flow), between 2016 Feb and 2020 Feb.



Pulmanki River study site. Note that the 25.5.2016, 23.5.2018 and 8.9.2018 are not shown, as from those times only the data from cs1 was analysed (cf. methods section). Their locations were within the cluster of other cs1 measurements.

Examples of streamwise velocity from different time steps (i.e. along stream)

PRELIMINARY RESULTS: FULLPAPER WILL BE SUBMITTED TO A JOURNAL IN MAY 2020



February 2016: example of ice-covered conditions, cs1 measurement location (bend inlet) Q=1.38 m^3/s

September 2016: example of autumn conditions, cs1 measurement location (bend inlet), Q=6.34 m^3/s

Feb 2017: another ice-covered situation, cs1 measurement location (bend inlet), Q=1.32 m^3/s

May 2017: spring snow-melt higher discharge, cs1 measurement location (bend inlet), Q=10.95 m^3/s

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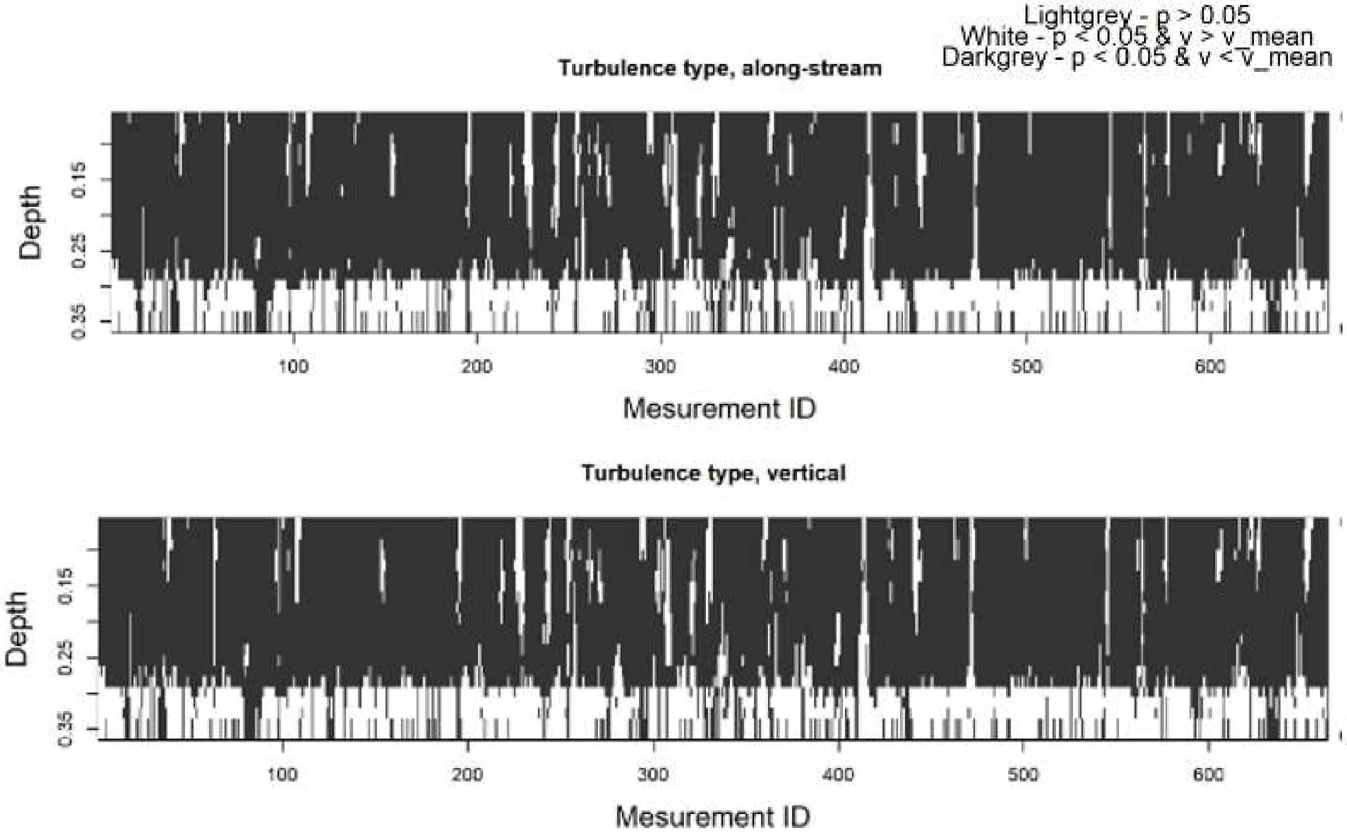
Autocorrelation of turbulence clusters (LISA analysis)

Note that these are examples and preliminary analyses of the work in progress

February 2016:
cs1 measurement location (bend inlet)

The white areas are satistically significant clusters of high flow and dark grey statistically significant low flow clusters.

Few clusters of high flow (reaching from surface layers to the bottom) in streamwise and vertical velocity.

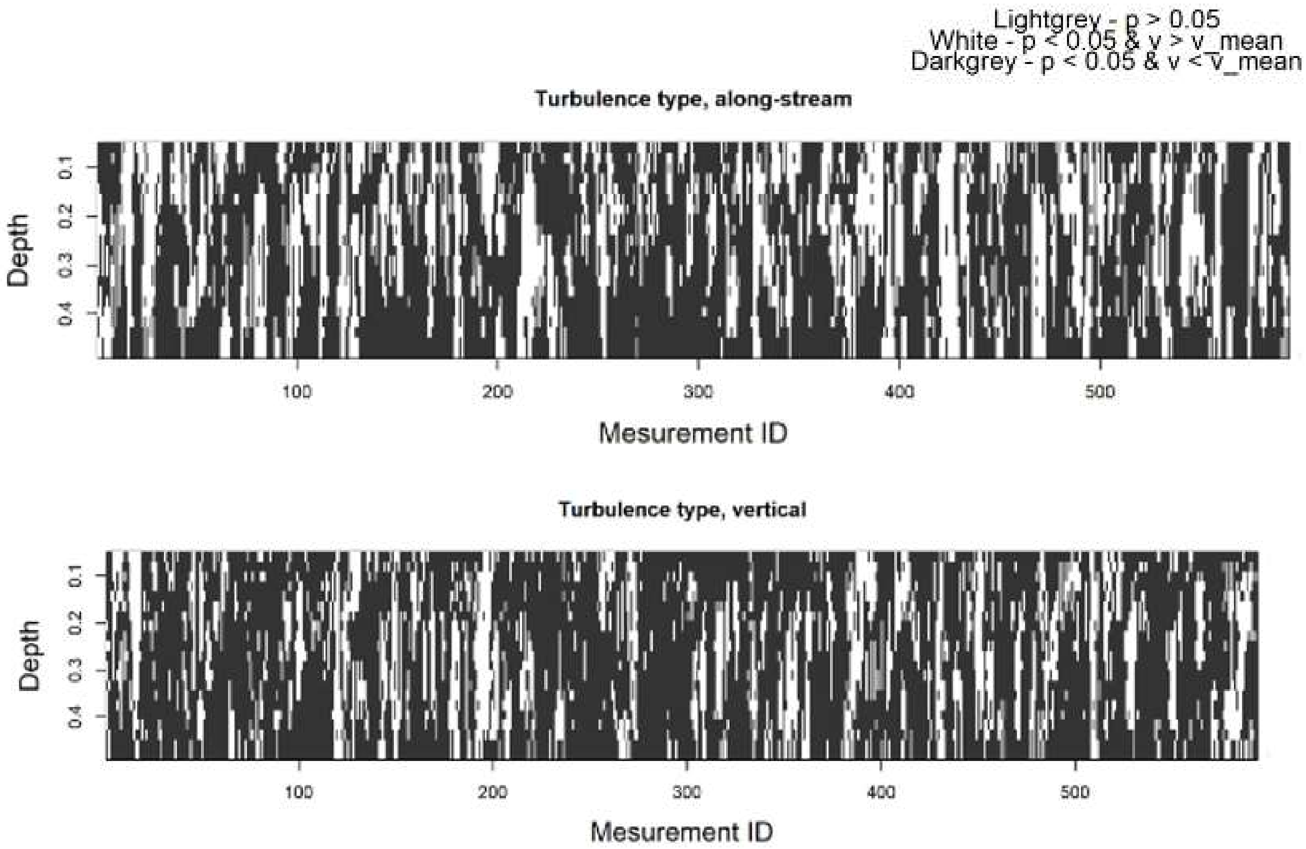


Measurement ID equals with sample number, i.e. seconds from the beginning of the measurement. 600 seconds is 10 minutes.

February 2016:
csB measurement location (bend apex)

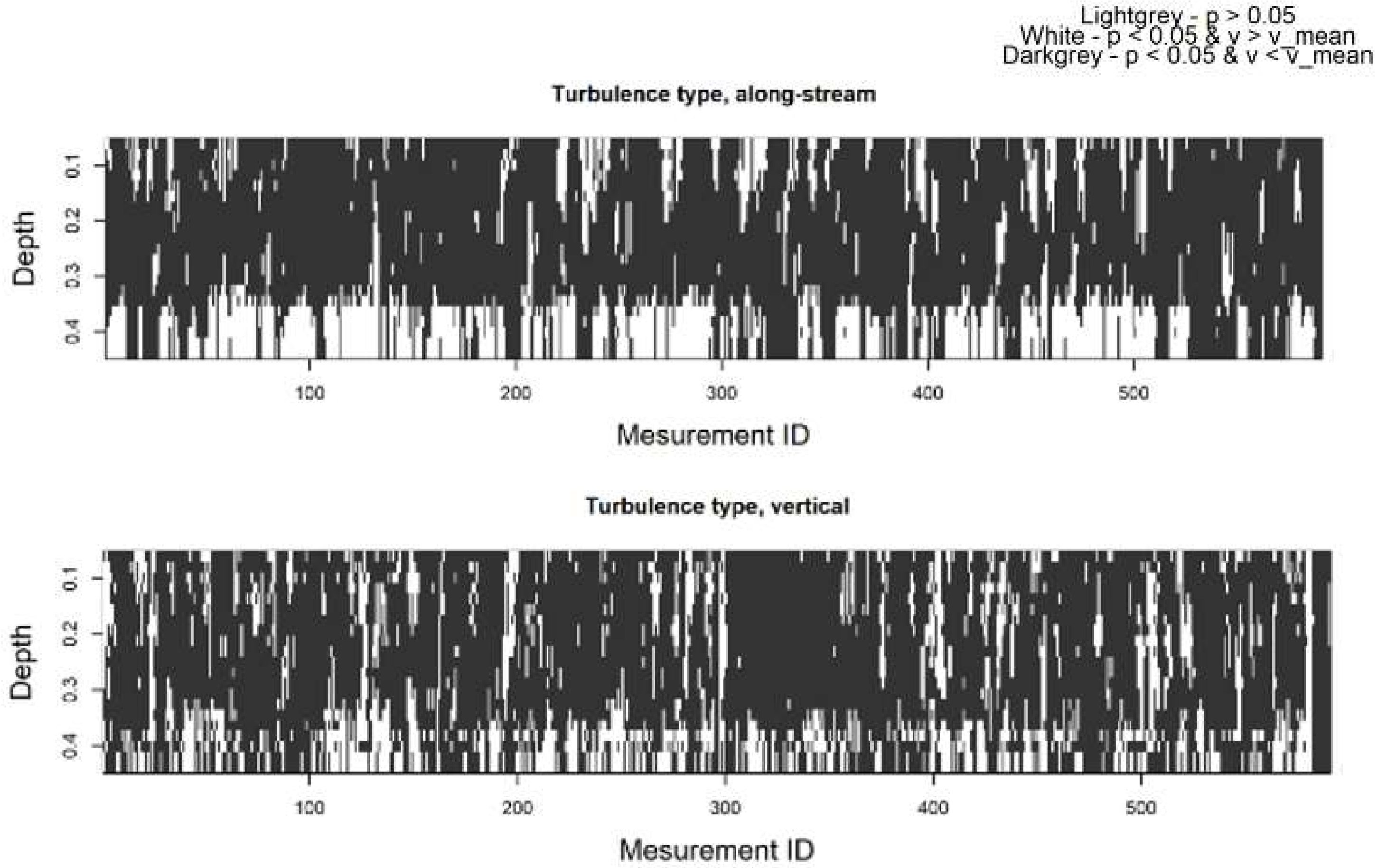
Clearer turbulence clusters reaching from top layers to bottom.

Thus, difference in turbulence structure along the meander bend.



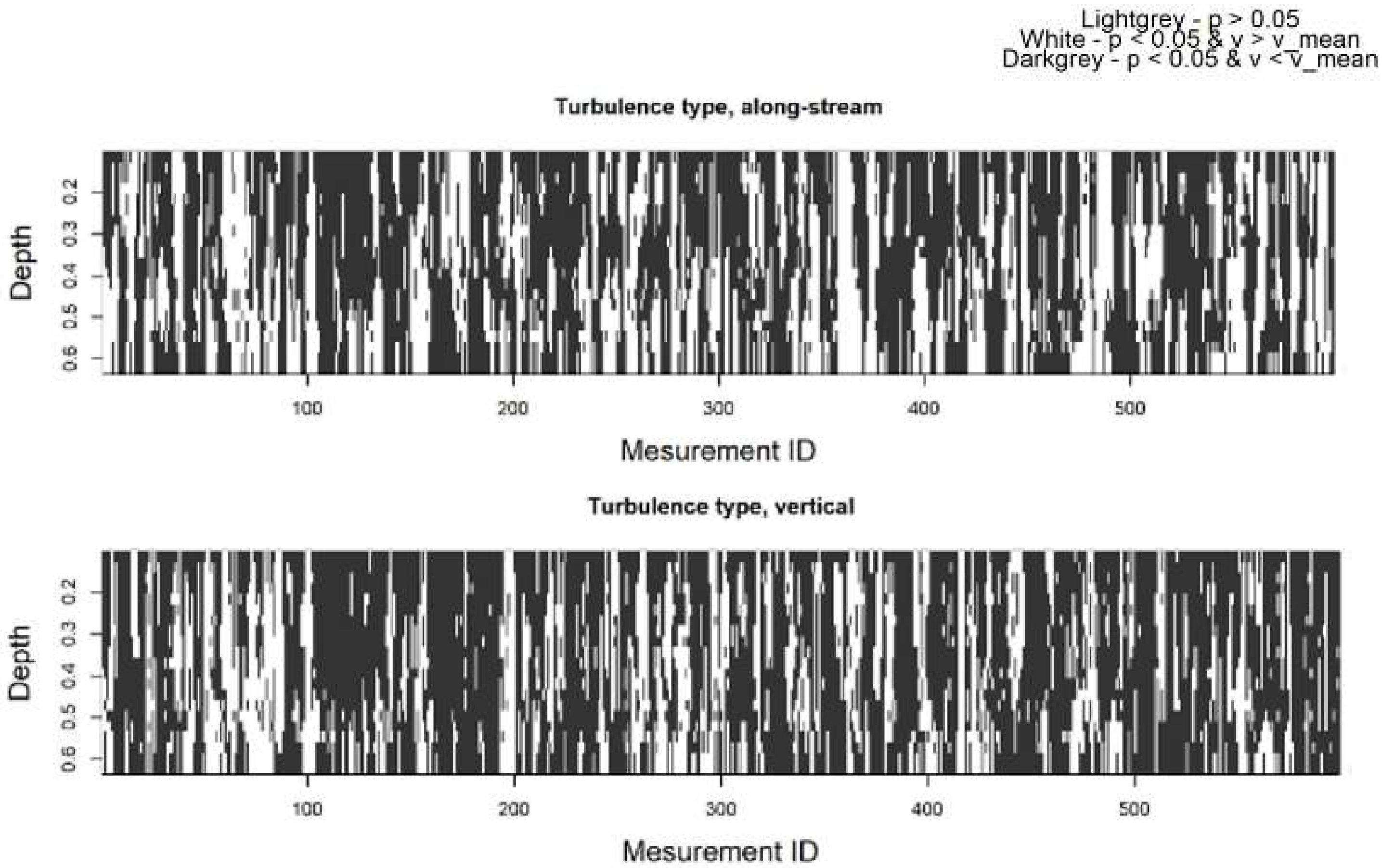
February 2016: cs4 measurement location (bend outlet)

Fewer clusters of high flow than in csB.



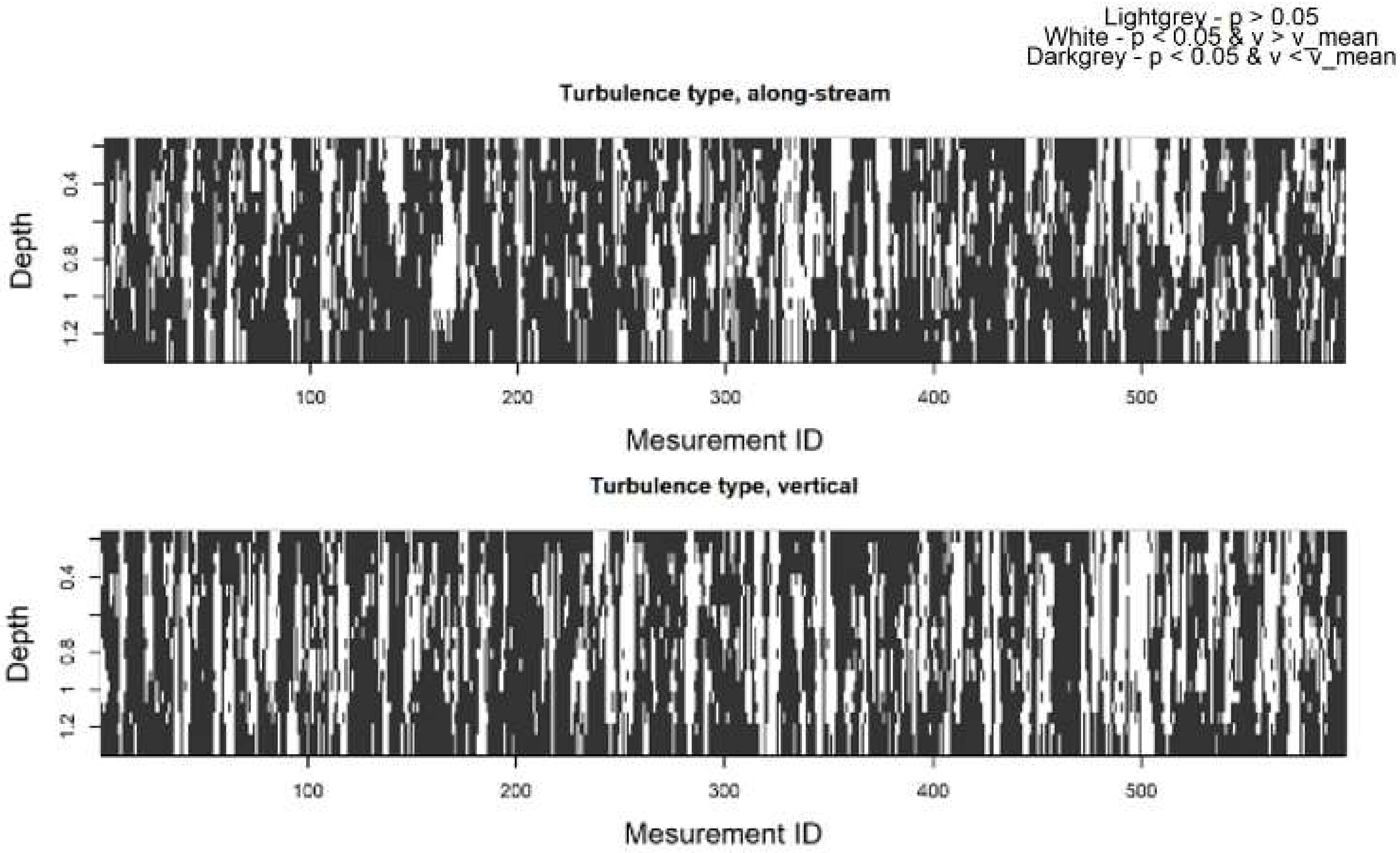
May 2017:
cs1 measurement location

Frequent variation of high and low flow clusters (both streamwise and vertical flow velocity).



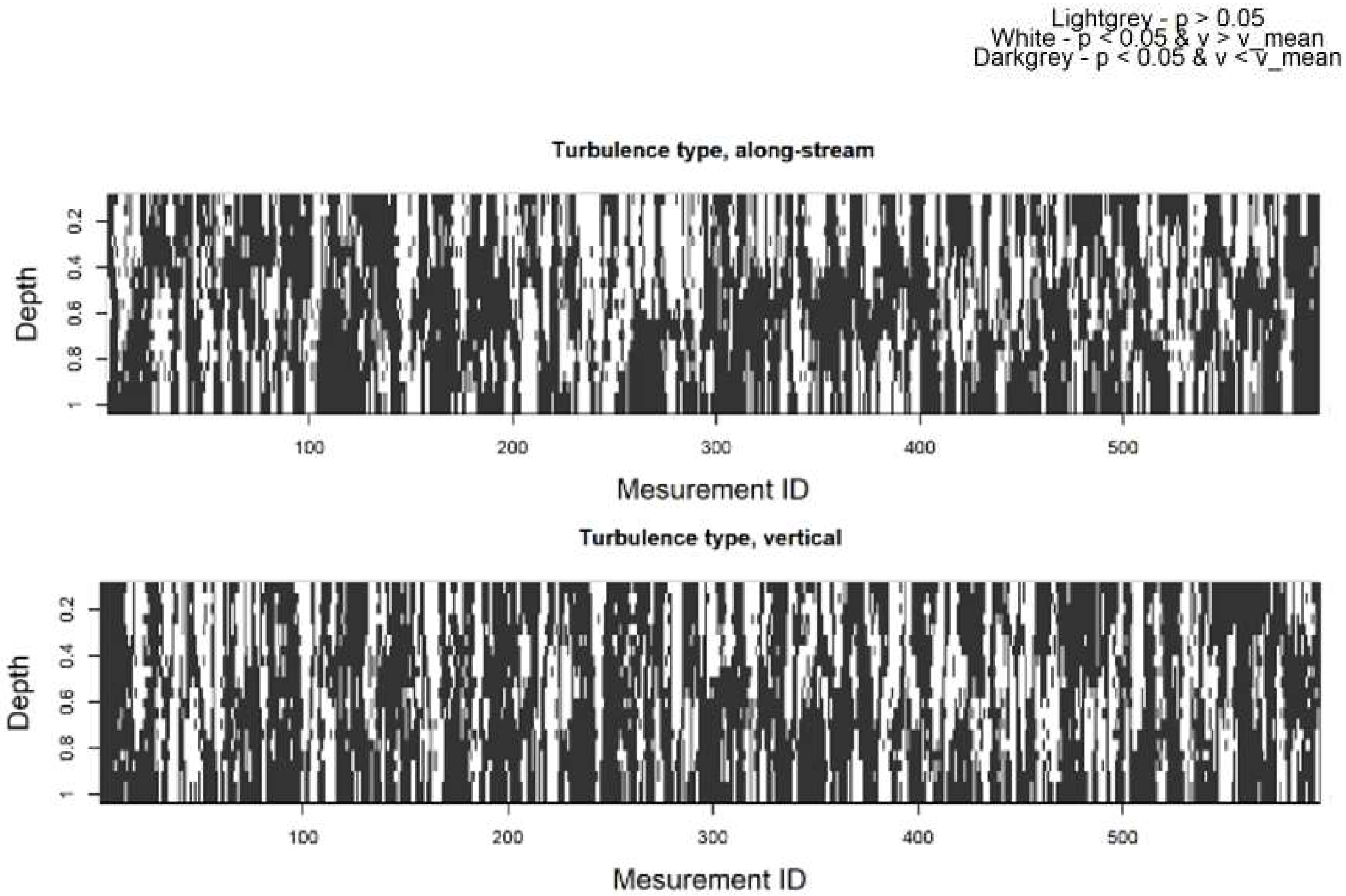
May 2017:
csB measurement location

Similarly to the upstream measurement location, frequentt variation of high and low flow clusters in streamwise and vertical velocities.

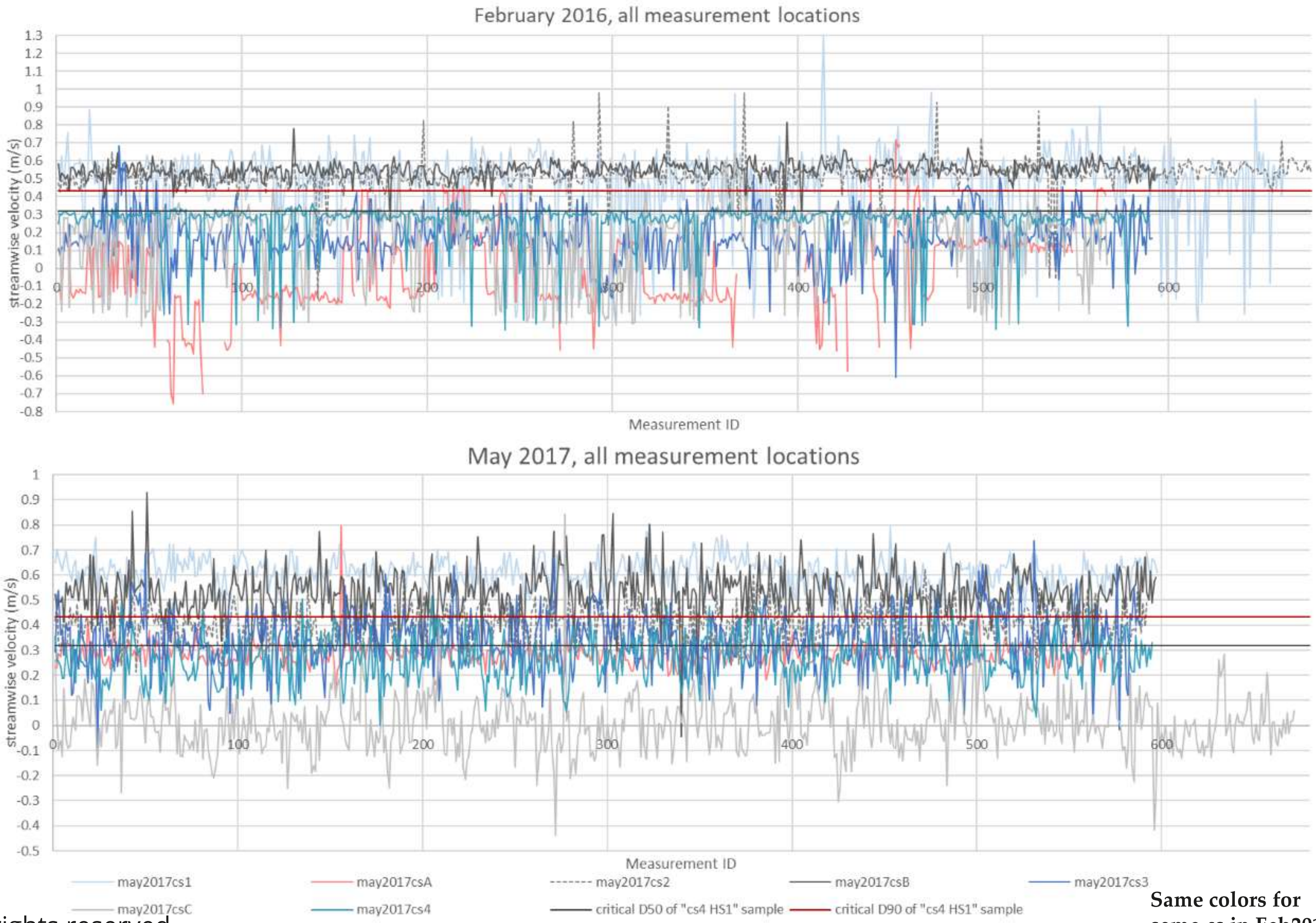


May 2017:
cs4 measurement location

Similarly to the other two measurement locations during May 2017 measurement time, frequent variation of high and low flow clusters occurred.



Near-bed velocities and critical velocity thresholds for sediment transport



Same colors for same cs in Feb2016

Conclusions

- Macroturbulent flow wedges were observed in every measurement location at the meandering Pulmanki River during ice-covered conditions and open-channel conditions, at least during some year.

- **1)** During the lower discharge conditions and lower streamwise velocity conditions, the vertical flow pulses were more clear than in the high discharge conditions.
  - During those winters, when the discharge was the lowest, ice thinnest and flow depth the greatest, there was least occurrence of the macro-turbulent flow structures, when compared to other winters.

- **2)** During high spring (May) discharge conditions, there was less differences in the macroturbulence between inlet, apex and outlet locations, than during lower discharge conditions of February and September.

- **3)** However, there were spatial differences between the inlet, apex and outlet areas, whether the threshold for motion was exceeded. The threshold for incipient motion was exceeded by the near-bed velocities during most of the measurement times at the inlet area.

- **4)** The frequency of the macroturbulence was the greatest during the measurement times having the greatest discharge conditions.
  - Despite the macroturbulent flow contributed on the sediment transport during the high discharge periods, during those measurement times the overall velocities were high.

- **5)** The macroturbulence was especially important for initiation of bed sediment movement during otherwise low flow situations, i.e. when the overall velocities were not high.

Thank you! / Kiitos!

E-mail: eliisa.lotsari@uef.fi

Web page: https://uefconnect.uef.fi/en/person/eliisa.lotsari/

ORC ID: http://orcid.org/0000-0002-0120-8722?lang=en