Observing and predicting streamflow intermittency across a mesoscale catchment

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Background

- Streams can be classified into ephemeral, intermittent and perennial streams
- Besides physical and biological indicators the classification can be based on streamflow duration

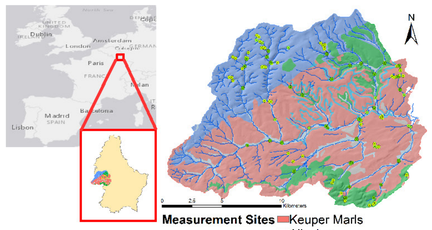
- Observation and prediction of streamflow intermittency
  - A) increases the understanding of hydrological functioning on a catchment scale
  - B) can support management implication for different stream types

- Presence of water in intermittent streams defines temporal streamflow continuity and spatial connectivity
- Measures which define spatial connectivity can help to predict intermittency

Objectives

1) Identification and development of suitable methods to monitor and quantification of streamflow intermittency
2) Identification and impact evaluation of landscape features which influence stream flow intermittency on the catchment scale
3) Quantification and evaluation of the role of the bedrock geology as a predictor of stream flow intermittency
4) Detection of changing patterns of streamflow intermittency between dry and wet system states

The Attert Catchment



Geology & Land Use:

- Devonian Slate (North, agriculture on plateau & valleys, forest on hillslopes)
- Keuper marls (Mid, mainly agriculture & pasture, patches of forest)
- Luxembourg Sandstone (South, mainly forested)

Climate:

- Yearly precipitation: 850mm
- Avg. Temperature: min.: 0°C (January)
- max.: 18°C (July)

Observations

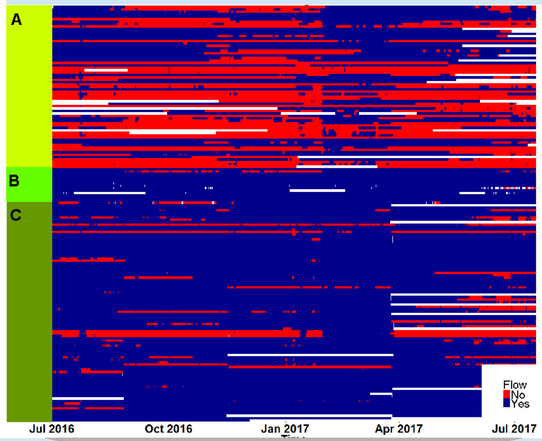
Presence and absence of streamflow measured by:

(A) Time-lapse imagery
- 70 sites
- intermittent/ephemeral streams
- Wildlife cam Dörr Snapshot Mini 5.0
- 15 min. time lapse interval
- visually analyzed flow presence.

(B) Water level sensors
- 17 sites
- intermittent /perennial streams

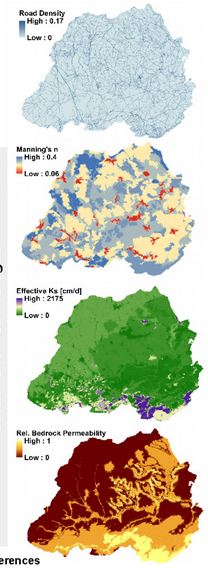
(C) EC sensors
- 88 sites
- mainly perennial streams
- modified HOBO Pendant Temperature/Light Data Logger
- installed at deepest point of the channel
- absence of flow defined at 25 µS threshold

Results



Predictions

Spatial Predictors



Roads & Tracks (Open Street Map)
- Road density / Track density
- Tracks & Curvature combined

Land Use (CORINE Landcover)
- Manning's n
- Catchment average Manning's n

Soil
- Catchment average effective Ks
- Catchment average usable field capacity

Terrain from DEM (15 m)
- Topographic Wetness Index (SAGA)
- Catchment Area (SAGA, D-8)
- Catchment Area Volumes
- Catchment Storage Height (SAGA)
- Average Catchment Slope (SAGA)
- Curvature (Planar, convex, combined)
- Topographic position index (TPI, SAGA)
- Vector Ruggedness Measure (SAGA)
- Mass Balance Index (MBI, SAGA)

Geology
- Catchment average relative permeability

Relative Intermittency

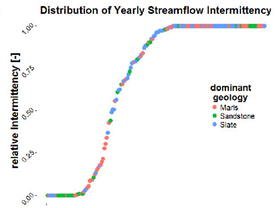
Relative Intermittency (*I*) is defined here as the ratio of times of flow presence T_F in a time period *T*.

$$I = T_F / T$$

The period 07/2016-07/2017 and one wet (Jan.-Mar.) and dry (Jun.-Aug.) period were examined in this study.

HEDERMAN & OSTERKAMP (1982) classify intermittent streams according to the flow duration per year.

< 0.1 *I*:	ephemeral
0.1 – 0.8 *I*:	intermittent
> 0.8 *I*:	perennial



Generalized Linear Model

Relative intermittency was modeled with a GLM developed with R-statistics

- Model *RI* ~ Spatial Predictors from GIS
- **5 Models:**
  - YearM: full time period, one year
  - Dry1 / Wet1: Independent models for dry summer/ wet winter period
  - Dry2 / Wet2: Parameter estimation for predictors from YearM-model for summer/winter period
- Logit-link, Quasibinomial Distribution
- Stepwise backward model selection based on QAIC
- Spatial application of GLM in a GIS, classification into intermittent & perennial

Significance and Influence of Model Parameters

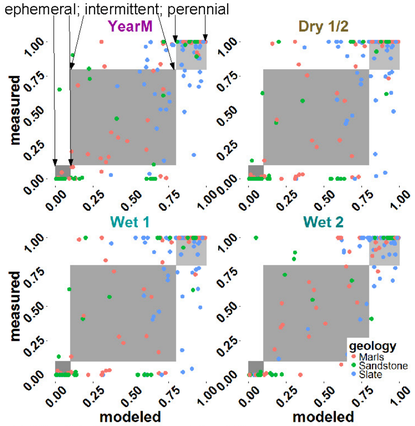
Parameter	YearM	Dry1	Wet1	Dry2	Wet2
Intercept	*** (-)	*** (-)	*** (-)	*** (-)	*** (-)
ln(Catchment Area)	*** (+)	*** (+)	*** (+)	*** (+)	*** (+)
Permeability	** (-)	** (-)		** (-)	* (-)
Effective K_s	* (+)	** (+)		** (+)	L (+)
Mass Balance Index	* (-)	* (-)	*** (-)	* (-)	*** (-)
ln(Catchment Area) * *ln*(Catchment Storage Height)	* (-)	** (-)		** (-)	L (-)
Catchment Average Tracks			* (-)		
Catchment Average Manning's n			L (+)		
Significance Codes	**P-Value: 0.000 =**	*** ; 0.001 = ** ; 0.01 = * ; 0.05 = L			
Modelled Stream Length [km]	**YearM**	**Dry1**	**Wet1**	**Dry2**	**Wet2**
Perennial (I > 0.8)	204	196	258	196	249
Intermittent (0.2 < I < 0.8)	368	359	321	360	313
Total	572	555	579	555	562

- The length of intermittent streams is higher during the wet season, at the same time the length of perennial streams shrinks:
  - A) Transition of intermittent to perennial streams during the wet season
  - B) Expansion of the total stream network

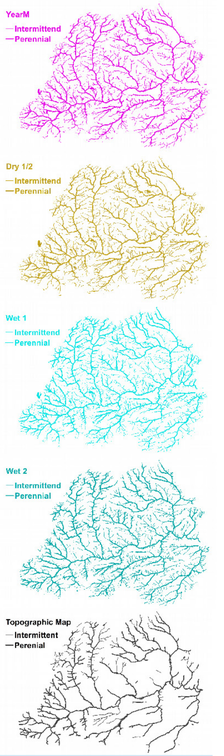
Predictions vs. Observations

- Model and Observations agree best in marl dominated areas
- Overall intermittency classes are modeled well
- Dry areas and ephemeral streams are not well represented in the model

ephemeral; intermittent; perennial



- Catchment area is the most influential predictor for all tested periods
- Bedrock permeability and the combination of catchment area and storage height (storage volume) dominate during the dry season
- During the wet season the terrain measures of catchment area and MBI dominate intermittency which is potentially an indicator the hydrological system is controlled by saturation. This is also well described with the topographic wetness index
- The importance of tracks seem to be bigger during the wet season ("preferential flow path"), while the roughness measure of Manning's n has the opposite effect



Conclusion

- Time lapse cameras are useful to monitor streamflow in places were conventional gauges cannot be installed
- EC measurements can support monitoring networks for intermittency through binary information on water presence

- Catchment area and bedrock permeability are most important predictors for intermittency
- Bedrock permeability and catchment volumes have the biggest influence during the dry season and lower influence during the wet season
- During the wet season terrain connectivity measures like catchment area and Mass Balance Index become most important predictors

- Spatial predictions of intermittency with GLMs are limited by number of monitoring sites and their spatial distribution

References
HEDERMAN E.R. & OSTERKAMP W.R. (1982): Streamflow Characteristics Related to Channel Geometry of Streams in Western United States. USGS Water-Supply. Paper 2193.

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