Deutscher Wetterdienst
Wetter und Klima aus einer Hand

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Umwelt und Verbraucherschutz
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Karlsruhe Institute of Technology

Towards Accurate Flood Predictions in Small, Fast-Responding Catchments Using Hourly CAMELS-DE Data

Alexander Dolich, Eduardo Acuña Espinoza, and Ralf Loritz

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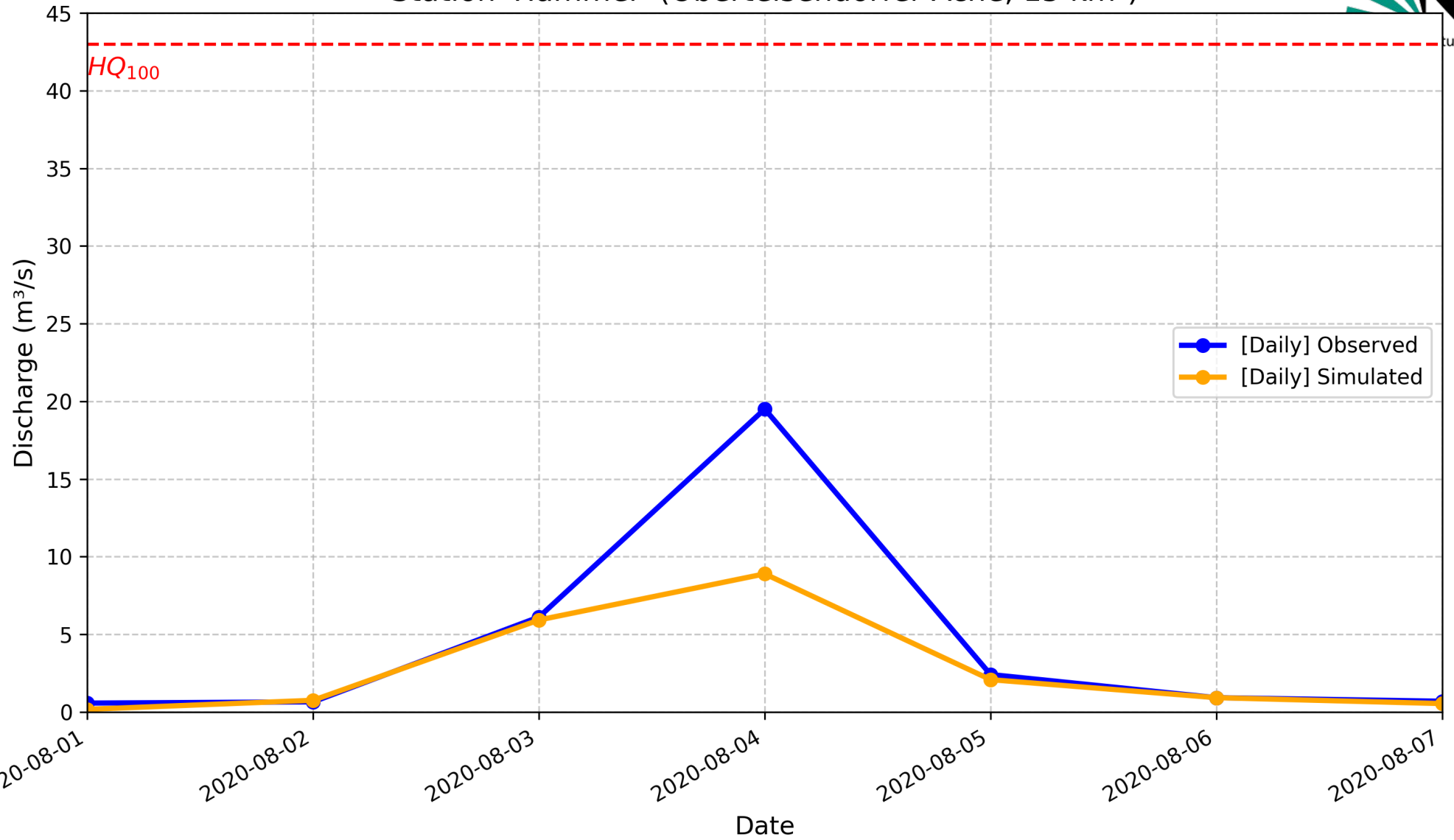
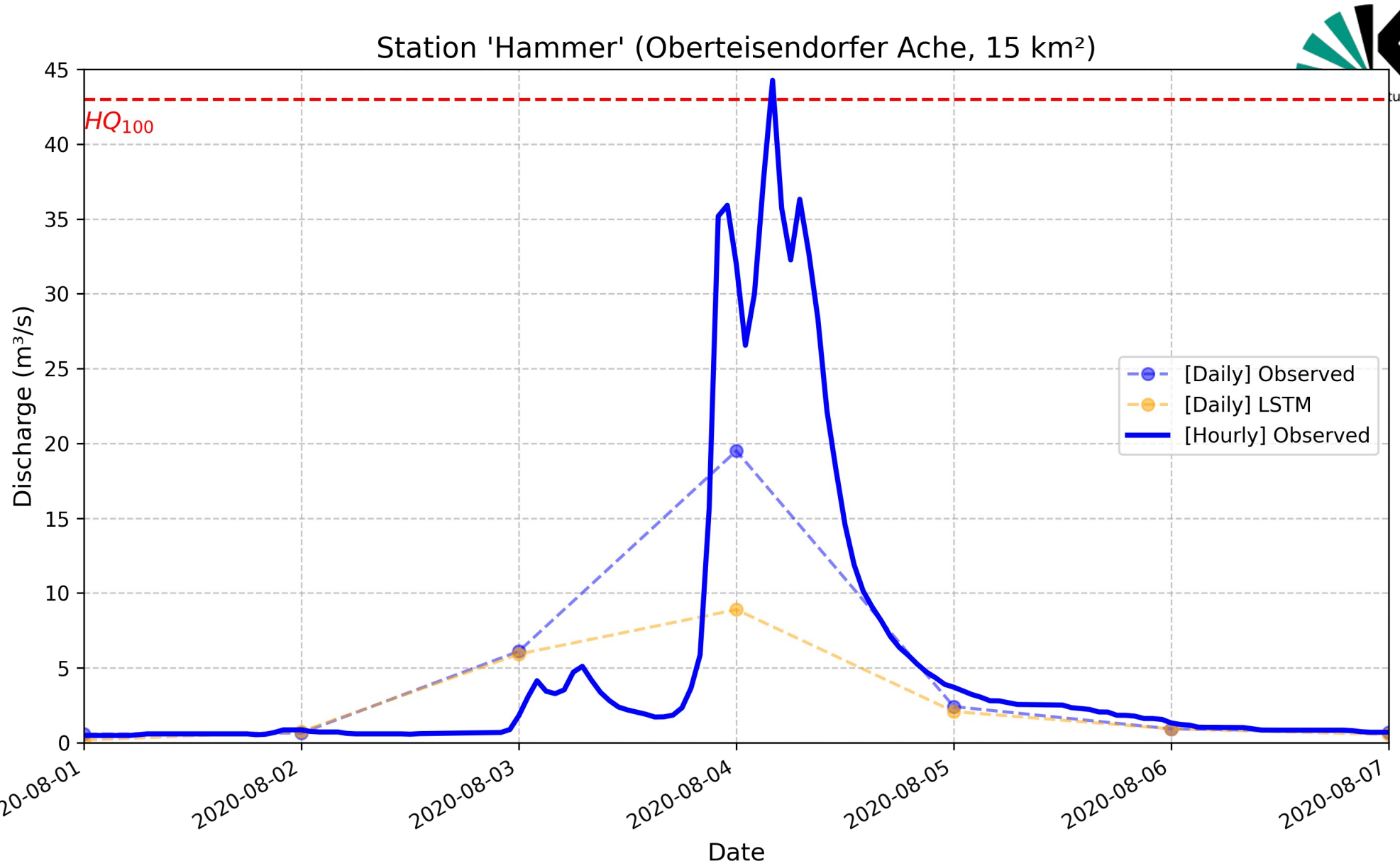

Station 'Hammer' (Oberteisendorfer Ache, 15 km²)
HQ_{100}
Discharge (m³/s)
0
5
10
15
20
25
30
35
40
45
2020-08-01
2020-08-02
2020-08-03
2020-08-04
2020-08-05
2020-08-06
2020-08-07
Date
[Daily] Observed
[Daily] Simulated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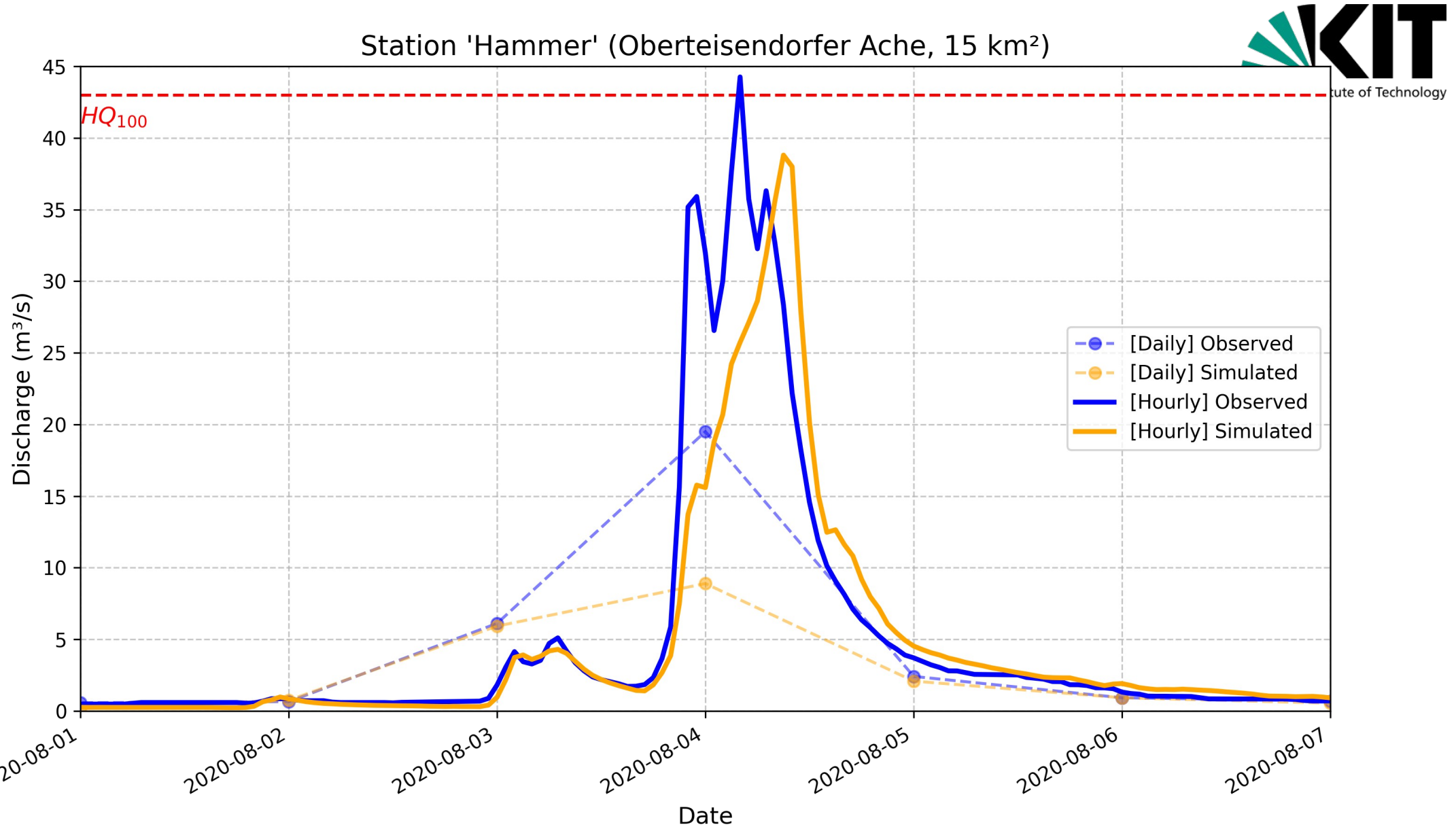
2020-08-03
2020-08-04
2020-08-05
2020-08-06
2020-08-07
Date
[Daily] Observed
[Daily] LSTM
[Hourly] Observed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Discharge (m³/s)
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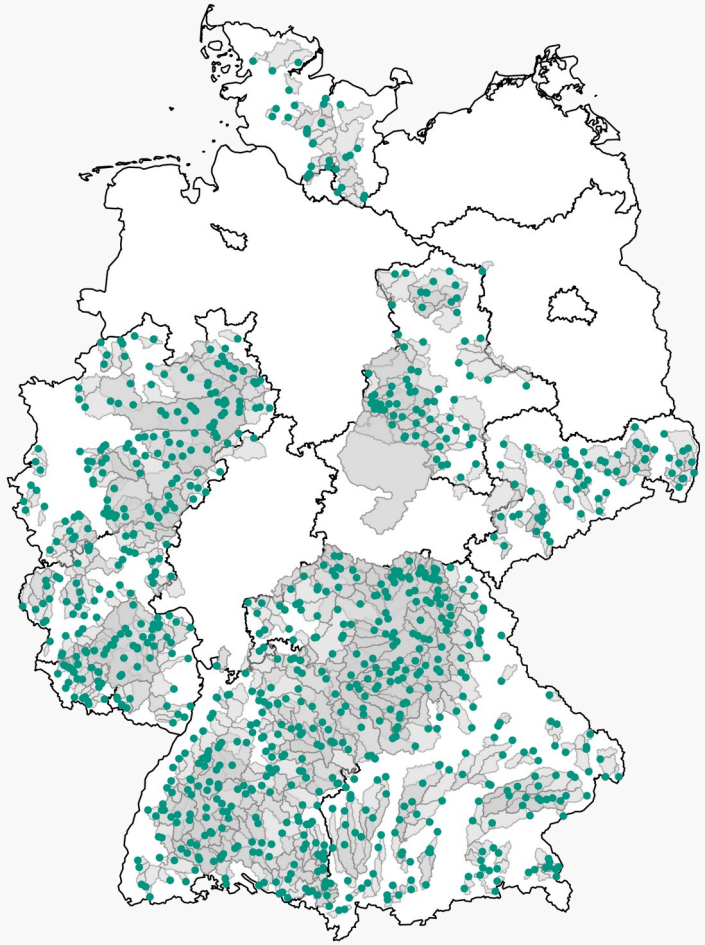
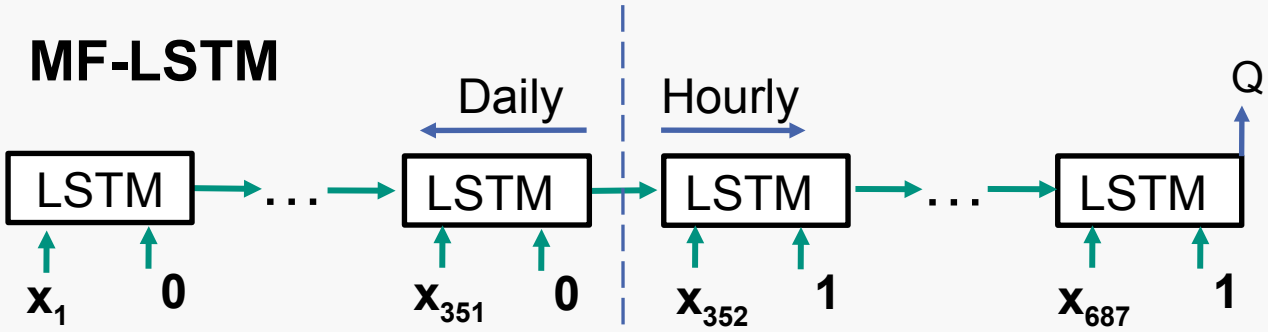
2020-08-06
2020-08-07
[Daily] Observed
[Daily] Simulated
[Hourly] Observed
[Hourly] Simulated

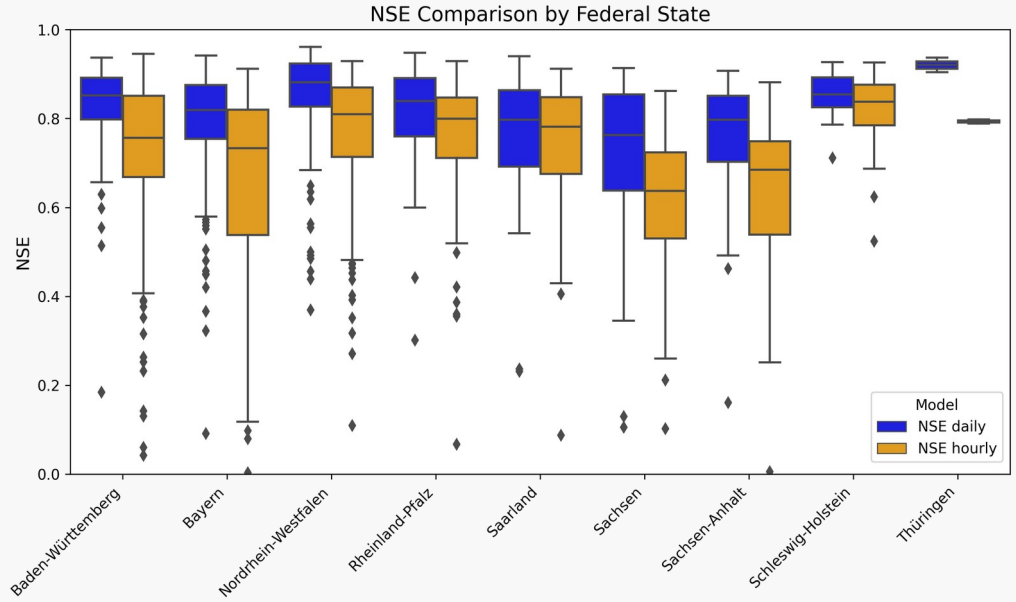
CAMELS-DE-1h



MF-LSTM

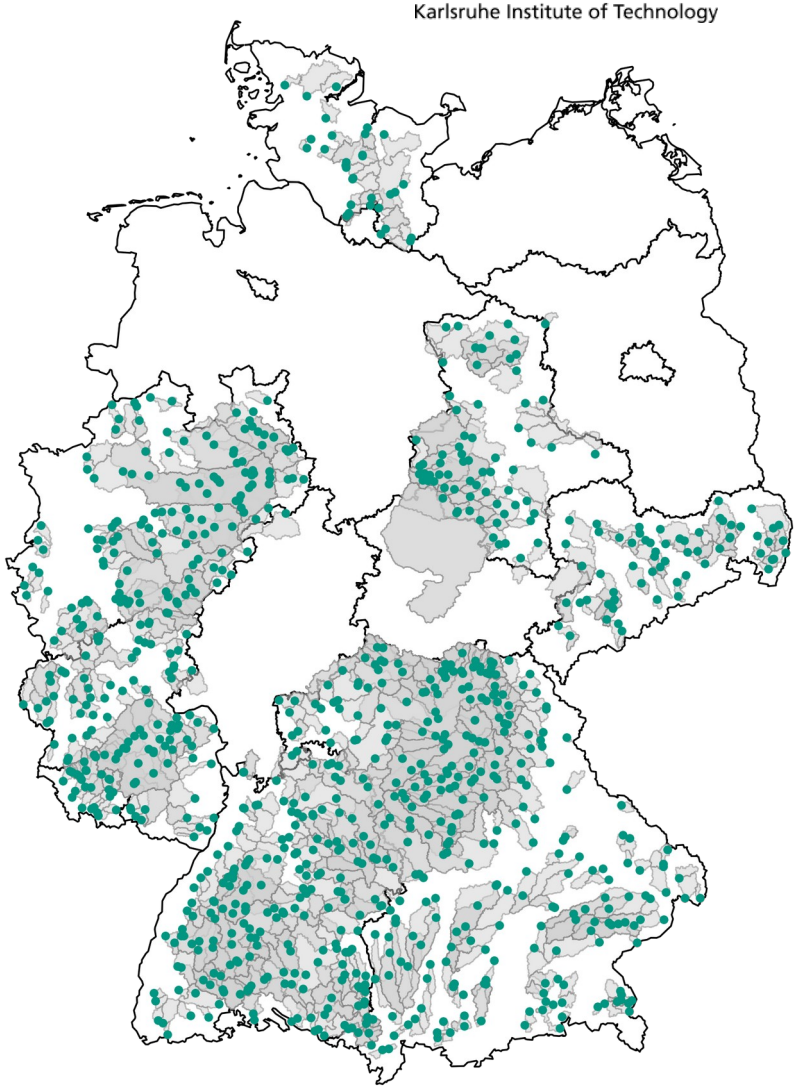


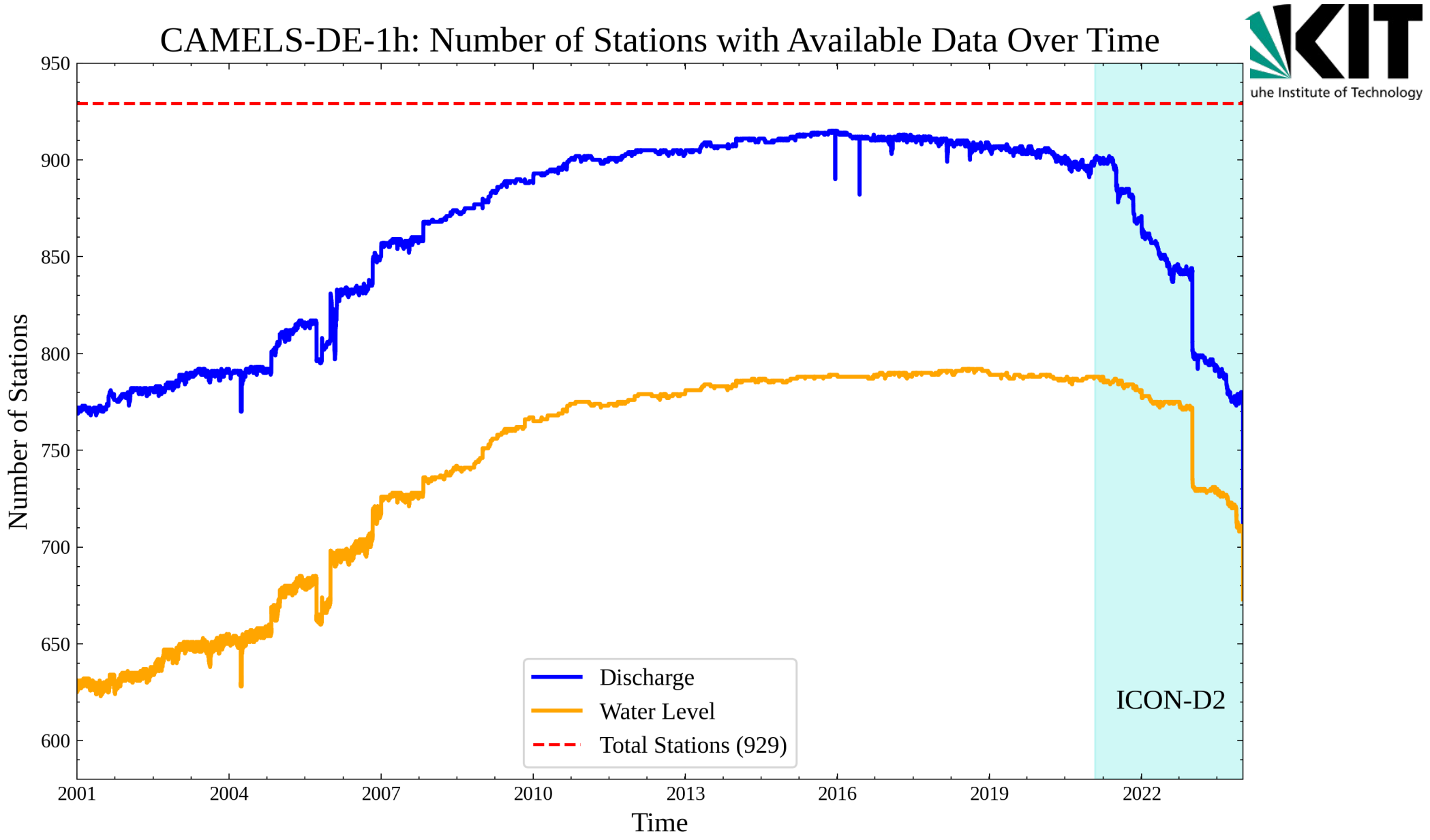
First results CAMELS-DE-1h

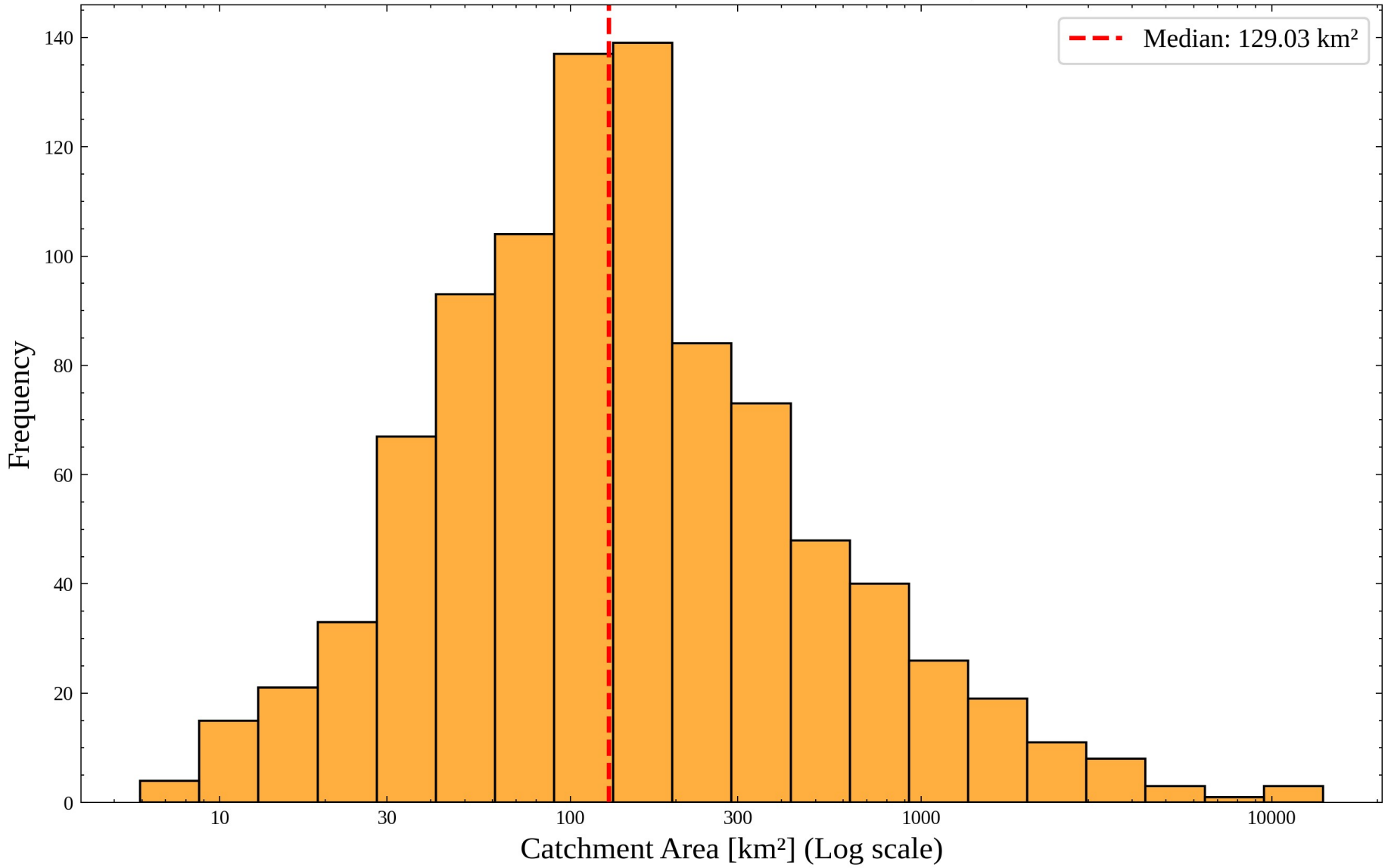


CAMELS-DE-1h (prelim.)

- 929 catchments, 9 federal states
- 2001 – 2023
- Hourly time series:
  - Discharge & water level
  - Catchment-aggregated meteorology (Radklim, Hostrada)
- Catchment attributes (topography, soil, land cover, …)



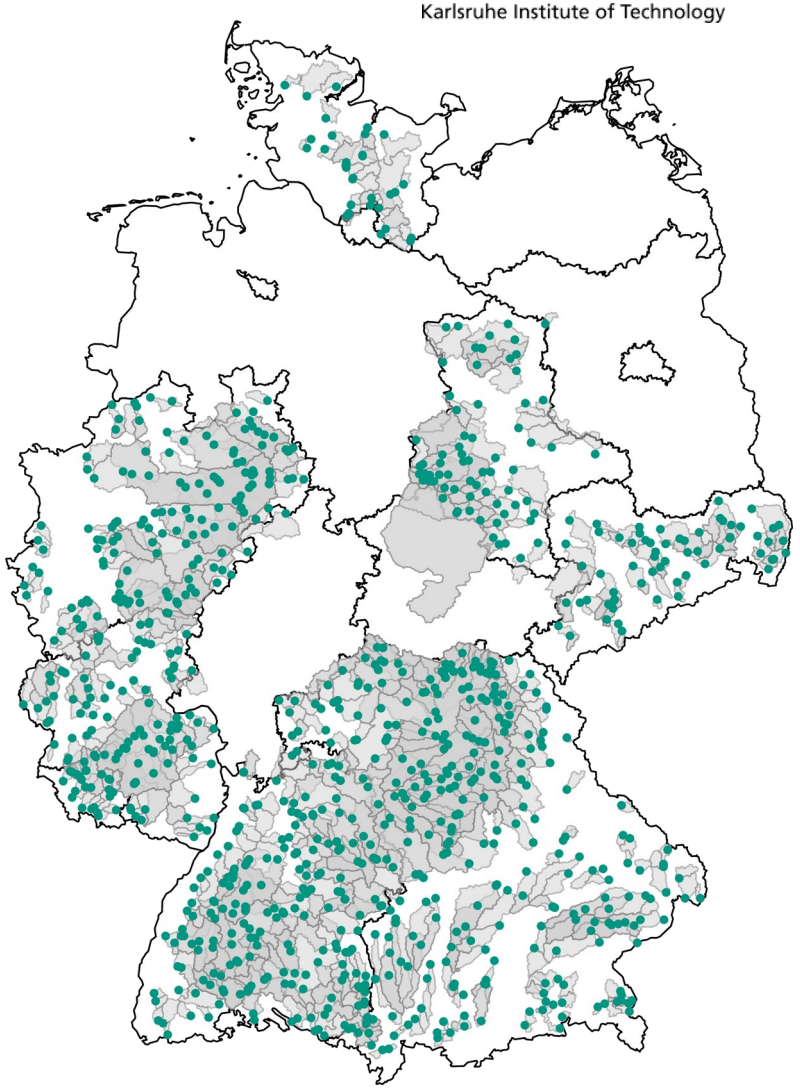

CAMELS-DE-1h: Number of Stations with Available Data Over Time
Number of Stations
Time
950
900
850
800
750
700
650
600
2001
2004
2007
2010
2013
2016
2019
2022
Discharge
Water Level
Total Stations (929)
ICON-D2


Catchment area sizes in CAMELS-DE-1h (929 stations)
Median: 129.03 km²
Frequency
0
20
40
60
80
100
120
140
10
30
100
300
1000
10000
Catchment Area [km²] (Log scale)

CAMELS-DE-1h: future plans

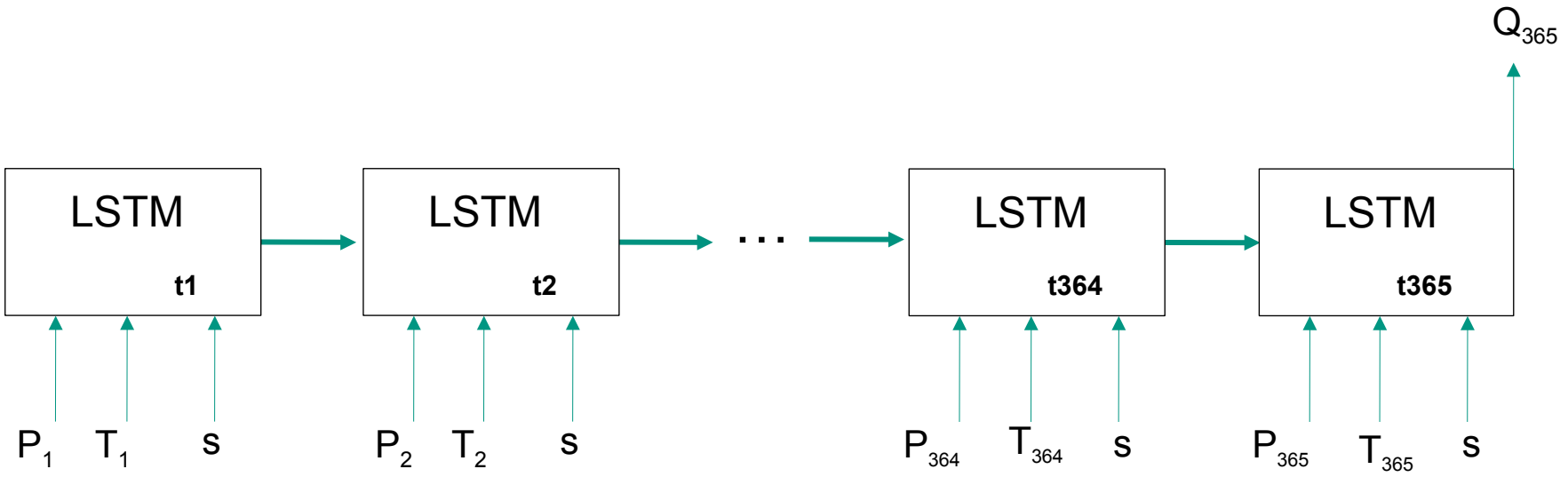
- Missing federal states: Niedersachsen, Mecklenburg-Vorpommern, Brandenburg, Hessen, (Thüringen)

- Forecast data: ICON-D2 (2021 – 2025)
  - Deterministic run / ensemble



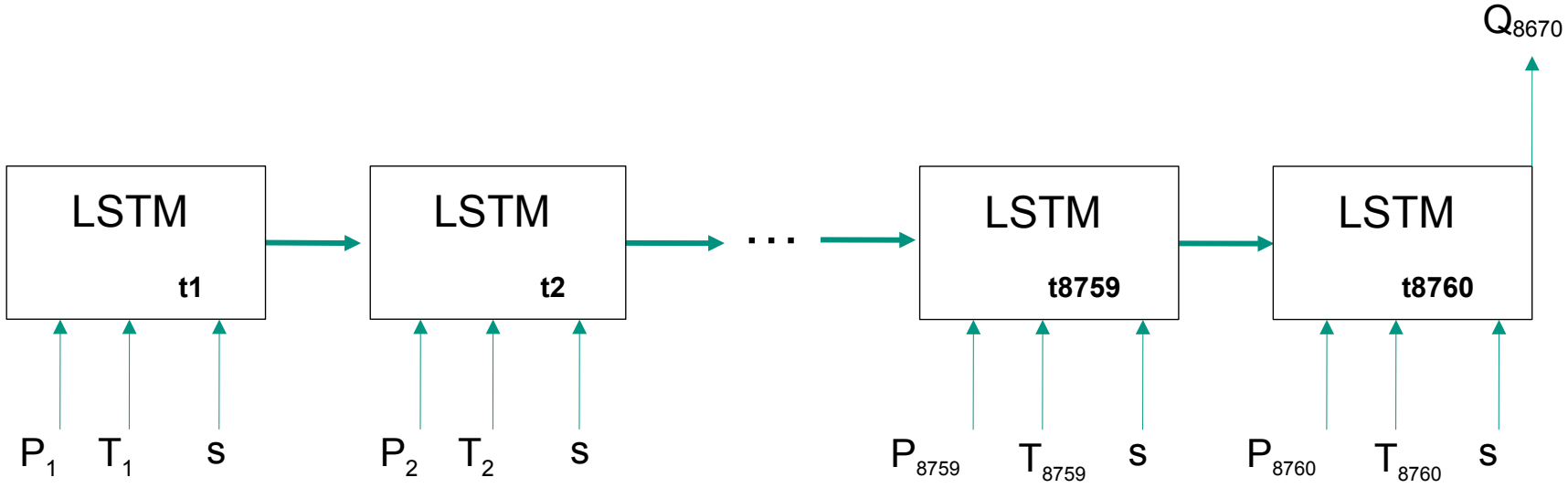
Daily to hourly data

- LSTMs need input from the past to simulate today's discharge
- State-of-the art studies:
  - Daily resolution
  - Sequence length of 1 year



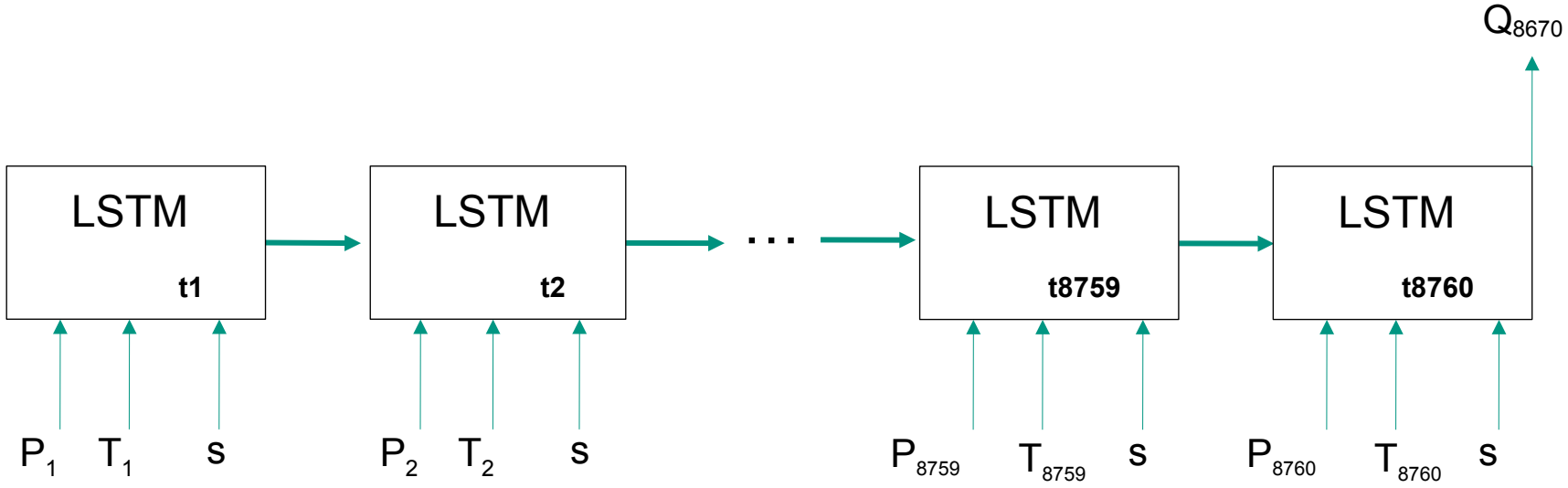
Daily to hourly data

- Simulations in small, fast responding catchments: hourly data needed
- 👍 capture an event's magnitude and shape (timing)
- 👎 using current state-of-the-art LSTMs: computationally very expensive
  - Sequence length: 365 timesteps → 8670 timesteps

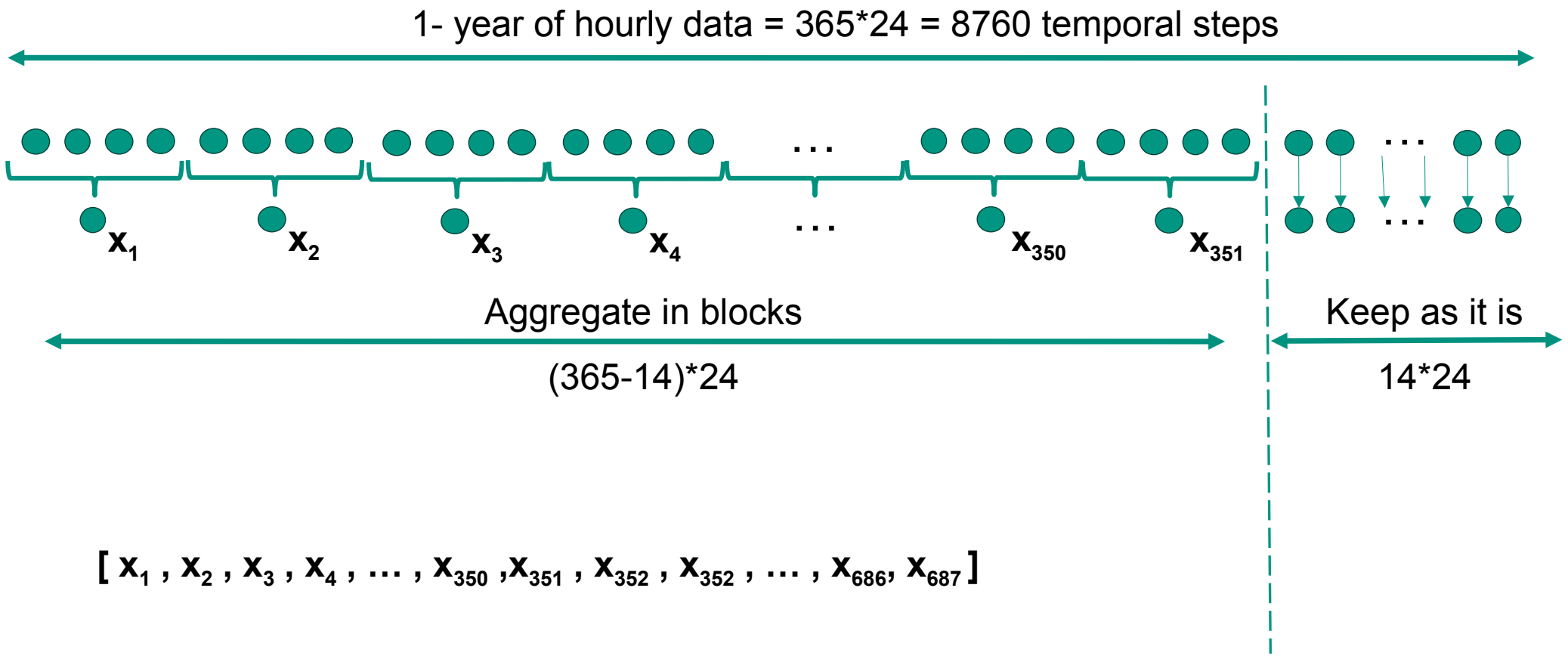


Daily to hourly data: solution

- Hourly resoluted data is only necessary in the near-past
- The further we are back in the sequence length, coarser resolutions are sufficient
- One LSTM that handles multiple frequencies: **MF-LSTM**

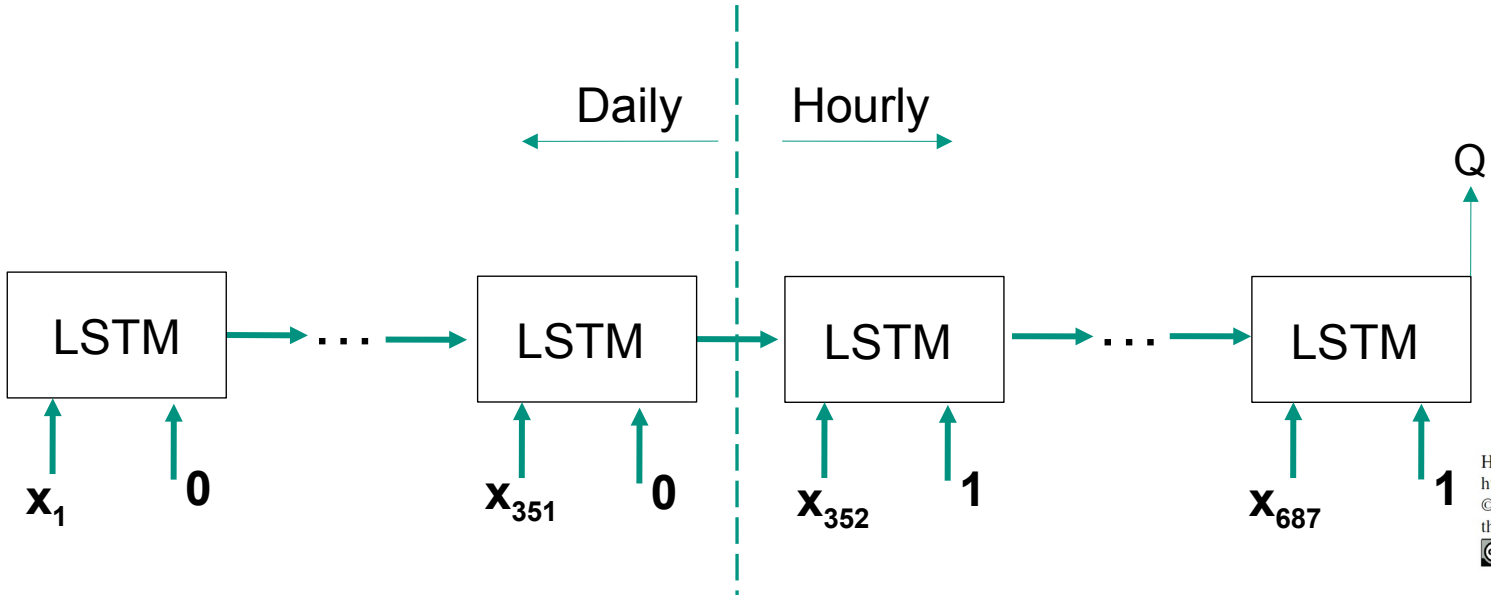


MF-LSTM: Multi-frequency LSTM



$[\, x_1 , x_2 , x_3 , x_4 , \dots , x_{350} , x_{351} , x_{352} , x_{352} , \dots , x_{686}, x_{687} \,]$

MF-LSTM: Multi-frequency LSTM



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https://doi.org/10.5194/hess-29-1749-2025

Hydrology and Earth System Sciences

Technical note: An approach for handling multiple temporal frequencies with different input dimensions using a single LSTM cell

Eduardo Acuña Espinoza[1], Frederik Kratzert[2], Daniel Klotz[2,3], Martin Gauch[4], Manuel Álvarez Chaves[5], Ralf Loritz[1], and Uwe Ehret[1]

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[3]Machine Learning in Earth Science, Interdisciplinary Transformation University Austria, Linz, Austria
[4]Google Research, Zurich, Switzerland
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MF-LSTM: Multi-frequency LSTM

Karlsruhe Institute of Technology

Oral | Friday, 02 May, 08:50–09:00 (CEST) Room 3.16/17

An approach for handling multiple temporal frequencies with different input dimensions using a single LSTM cell

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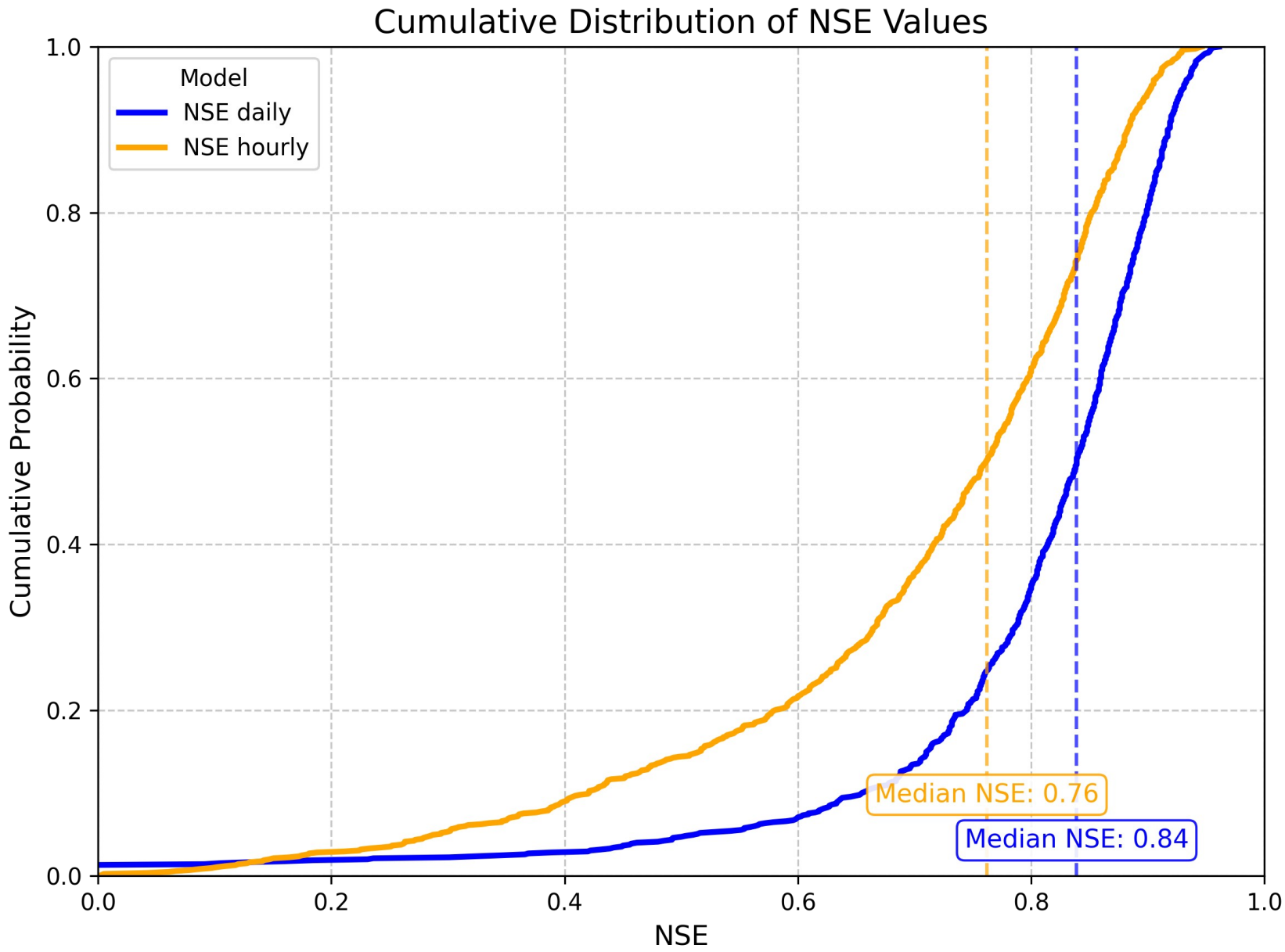
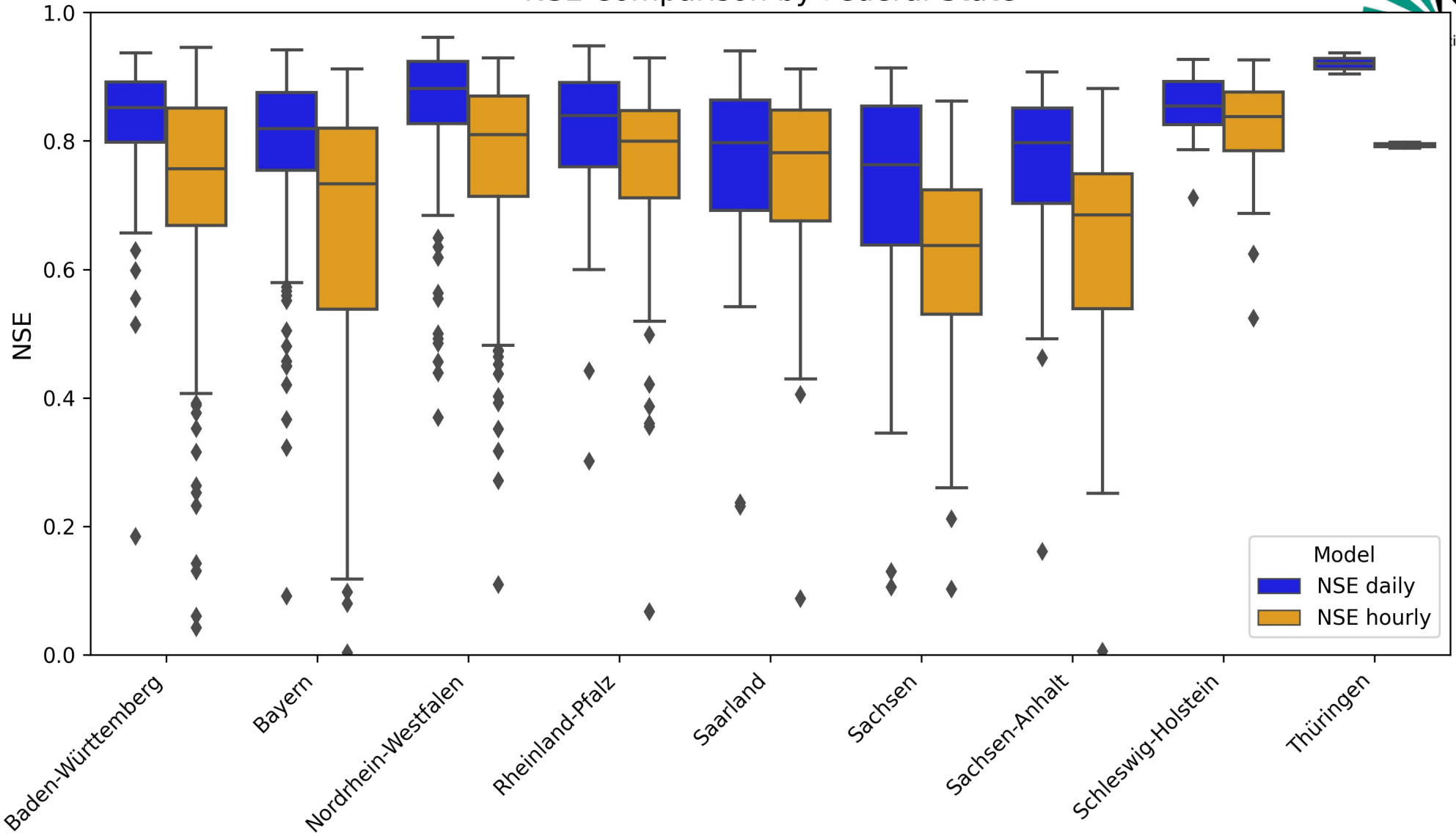
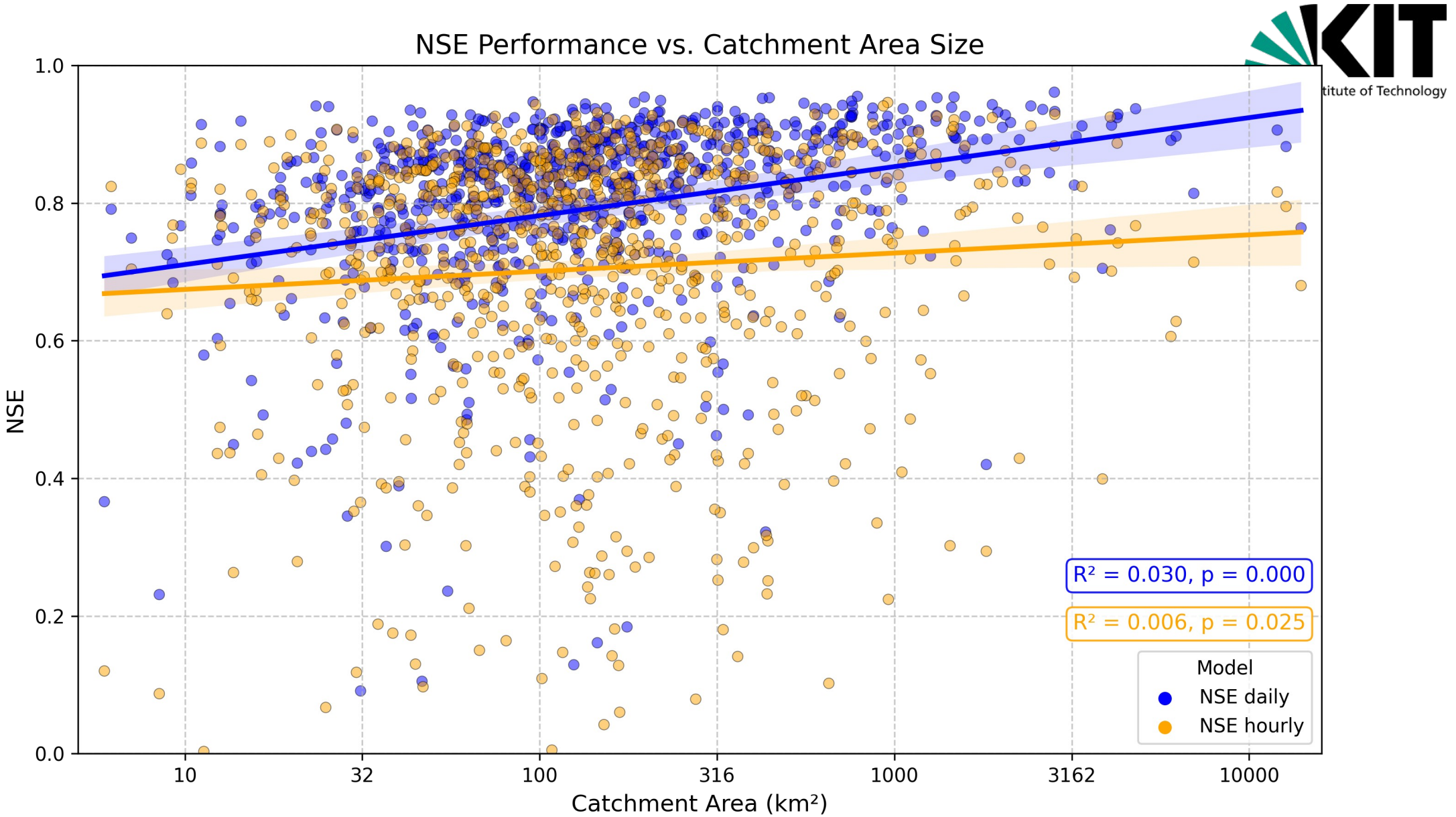

Cumulative Distribution of NSE Values
Model
NSE daily
NSE hourly
Cumulative Probability
NSE
0.0
0.2
0.4
0.6
0.8
1.0
Median NSE: 0.76
Median NSE: 0.84


NSE Comparison by Federal State
NSE
1.0
0.8
0.6
0.4
0.2
0.0
Model
NSE daily
NSE hourly
Baden-Württemberg
Bayern
Nordrhein-Westfalen
Rheinland-Pfalz
Saarland
Sachsen
Sachsen-Anhalt
Schleswig-Holstein
Thüringen


NSE Performance vs. Catchment Area Size
NSE
Catchment Area (km²)
1.0
0.8
0.6
0.4
0.2
0.0
10
32
100
316
1000
3162
10000
R² = 0.030, p = 0.000
R² = 0.006, p = 0.025
Model
NSE daily
NSE hourly