

# Snelle probabilistische inundatie verwachtingen met cloud computing en deep learning

Fedde Hop

**HydroLogic**

**UNIVERSITY  
OF TWENTE.**

Begeleiders:

Ralf Linneman (HL)

Bram Schnitzler (HL)

Anouk Bomers (UT)

Martijn Booij (UT)

# Introductie

- Afstuderen Universiteit Twente
- Afgerond op 27 januari
- In dienst HydroLogic

*Hydro*Logic

**UNIVERSITY  
OF TWENTE.**

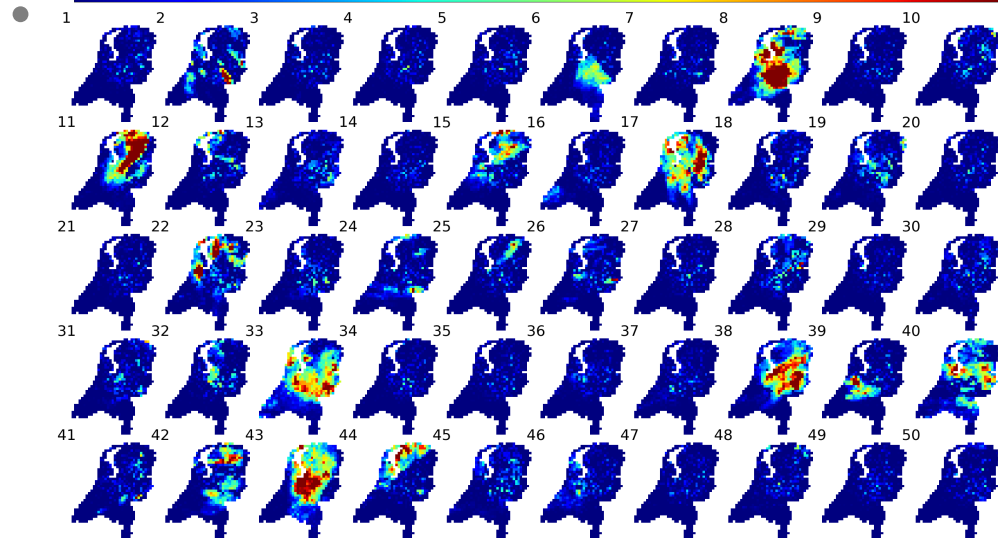




# Introductie

- Extreme neerslag -> inundatie
- Inundatie voorspellen
- Onzekerheid neerslag voorspelling

Droog  Heftige regenval

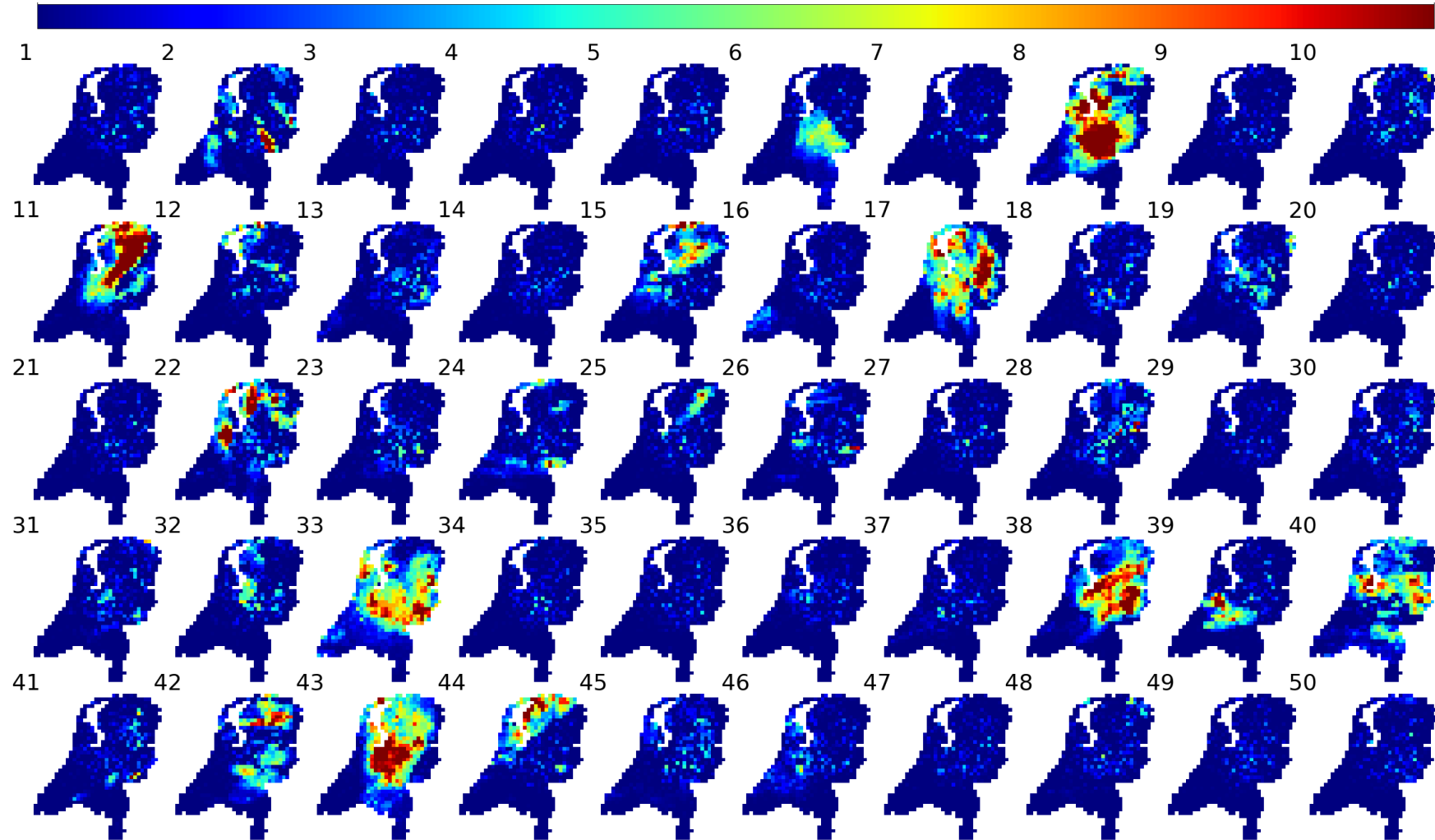


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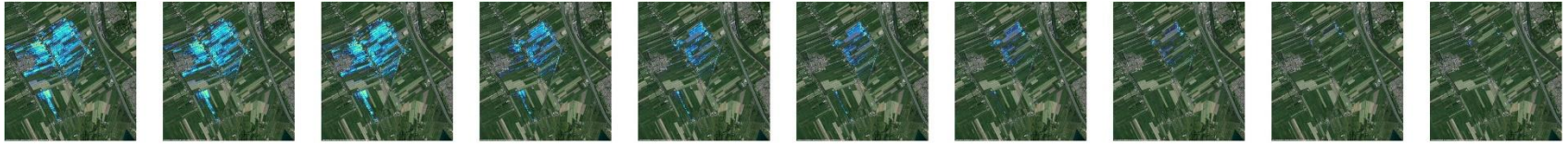


Droog

Heftige regval

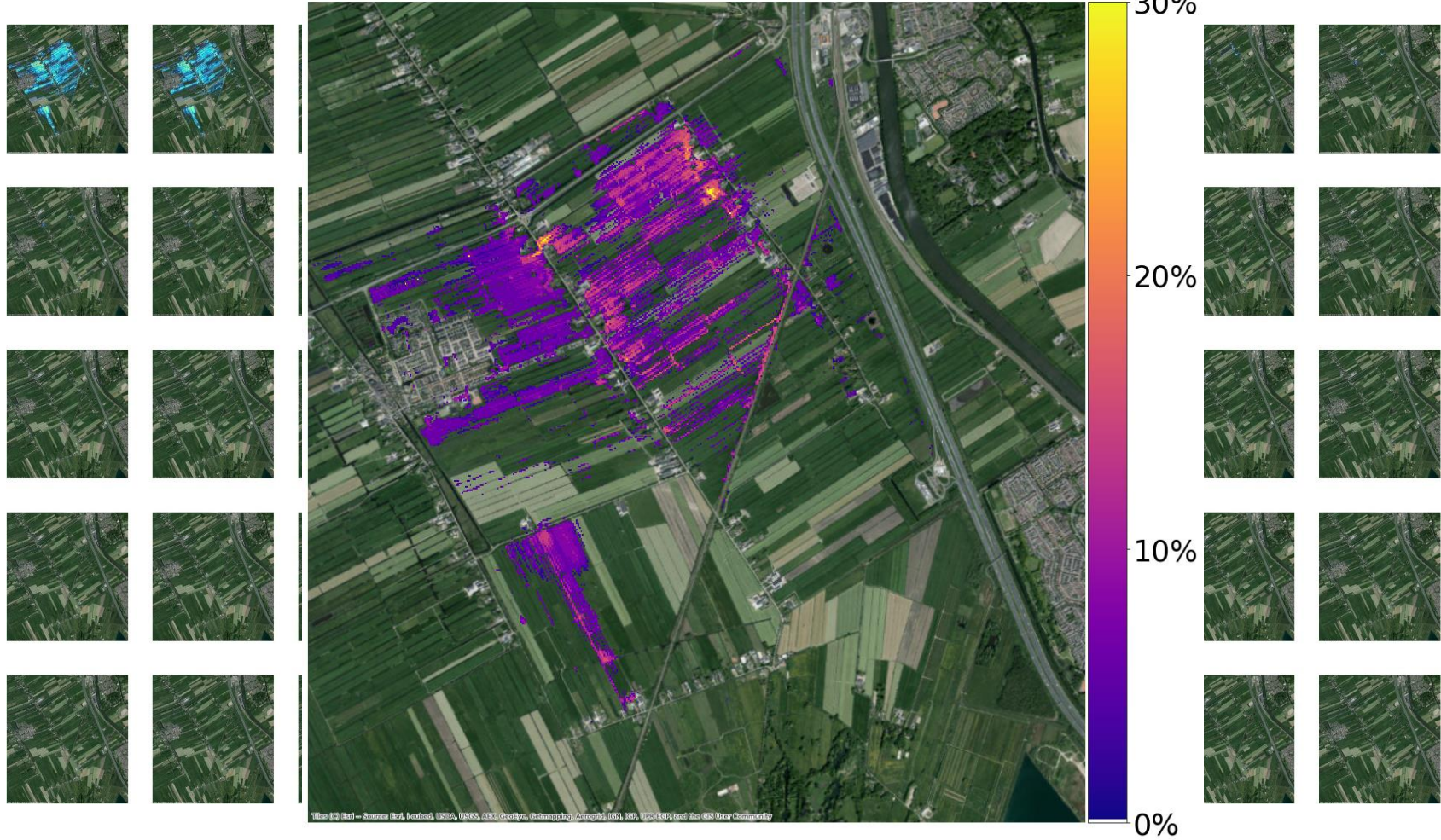








# Kans op inundatie boven de 5.0 cm



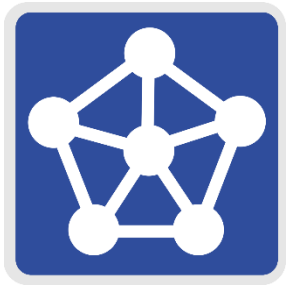
# Introductie

- Probabilistische inundatie voorspelling
  - 50 inundatie voorspellingen
    - één voor elke neerslag voorspelling
  - kansen berekenen
  - langzaam
- Versnellen
  - cloud computing
  - neuraal netwerk



# Introductie

- 3 onderdelen
  1. D-HYDRO model maken
  2. Cloud workflow
  3. *Neuraal netwerk*





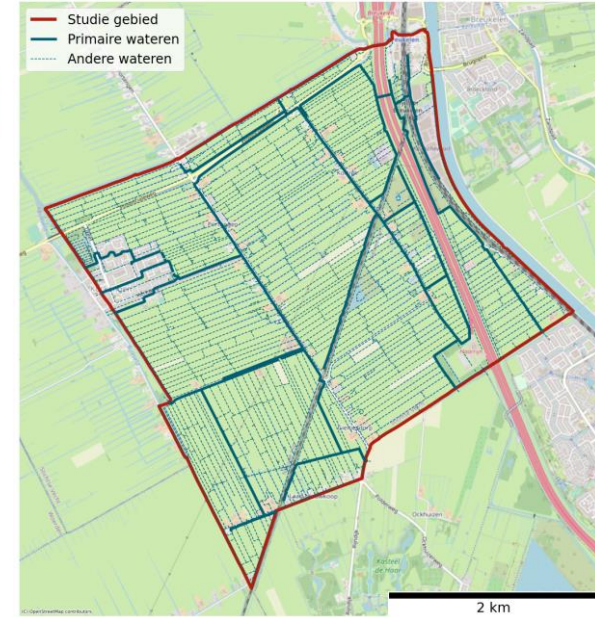
# HydroLogic

The background of the slide is a complex digital interface. It features a grid of numerous rectangular panels, each displaying different types of data visualizations. These include satellite-style maps of landmasses, abstract data plots with glowing points and lines, and various charts. The overall aesthetic is high-tech and blue-toned, with a perspective that makes the panels appear to recede into the distance.

D-HYDRO model

# D-HYDRO model

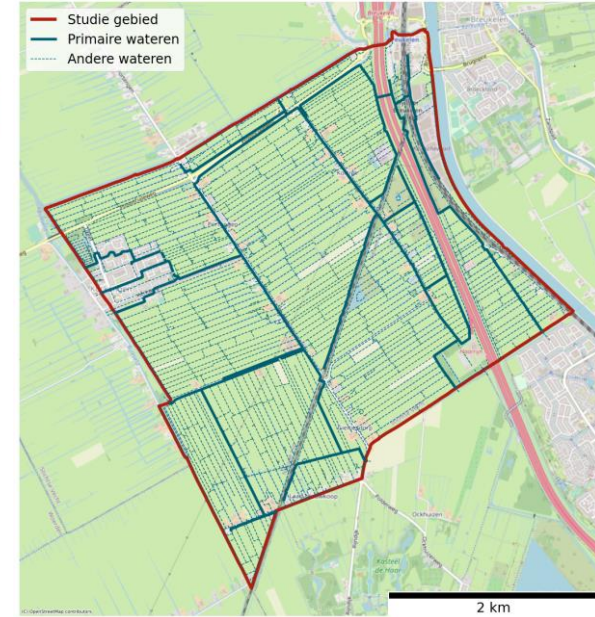
- Polder de Tol
- 1D2D + RR model
- 2D grid
  - vierkante cellen
  - 10 meter resolutie
  - 123.993 cellen
- D-HYDAMO
  - Python
- Gekalibreerd
- Rekentijd: 5-15 minuten





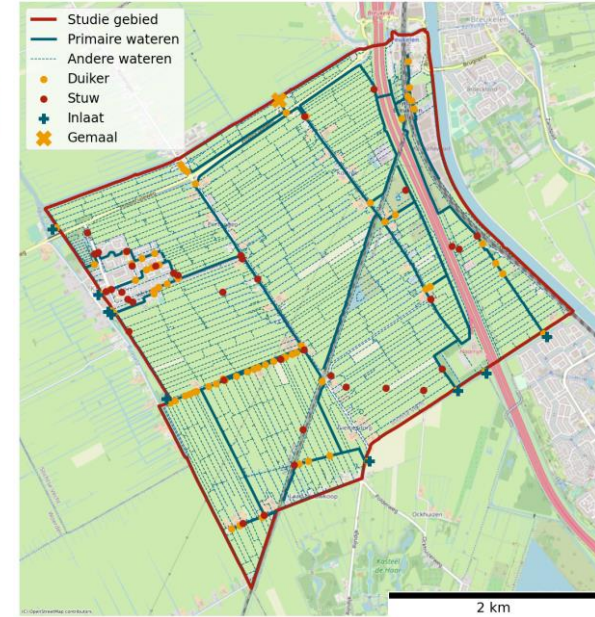
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# D-HYDRO model

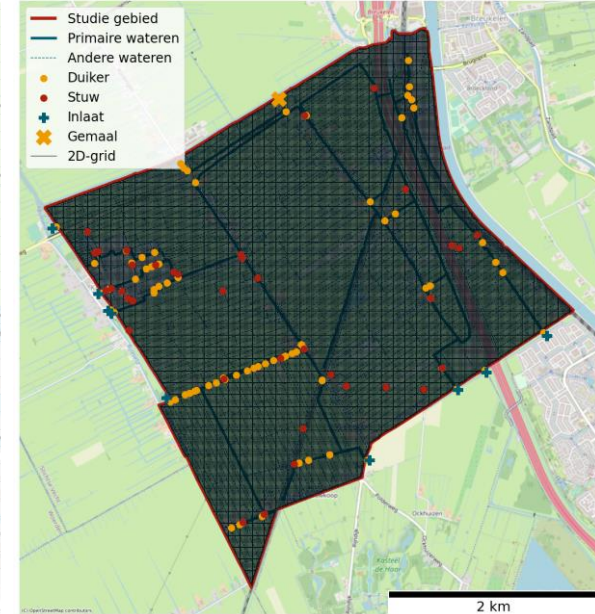
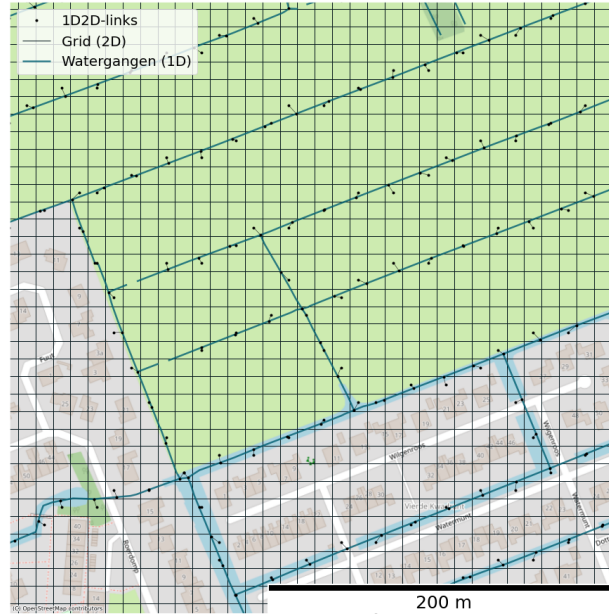
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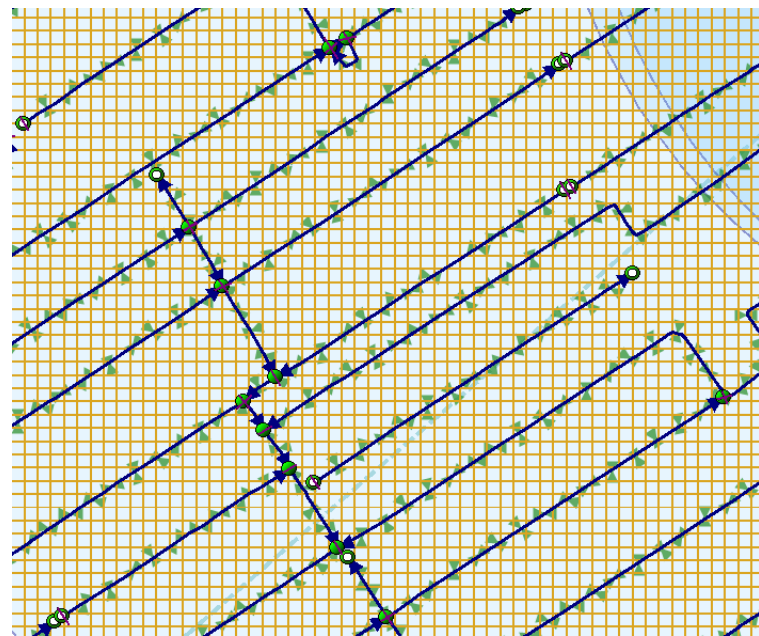
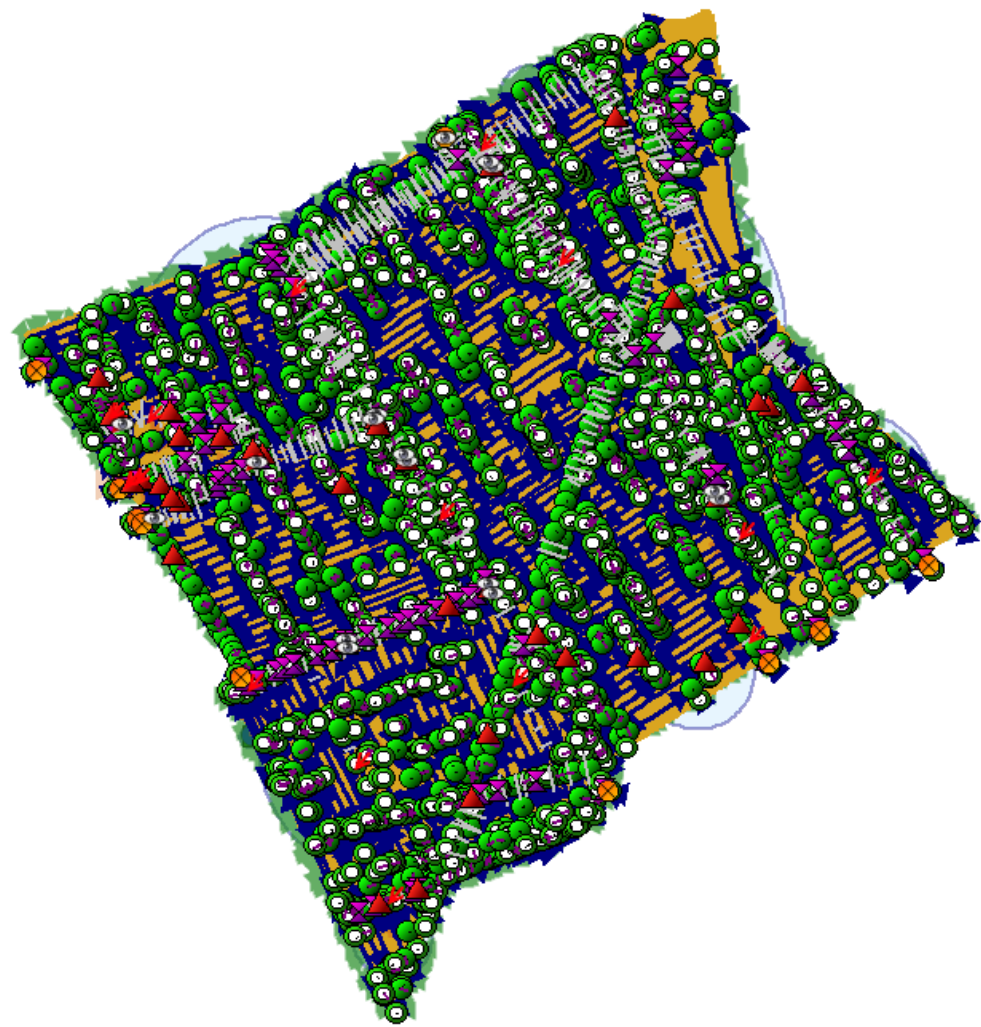




# D-HYDRO model

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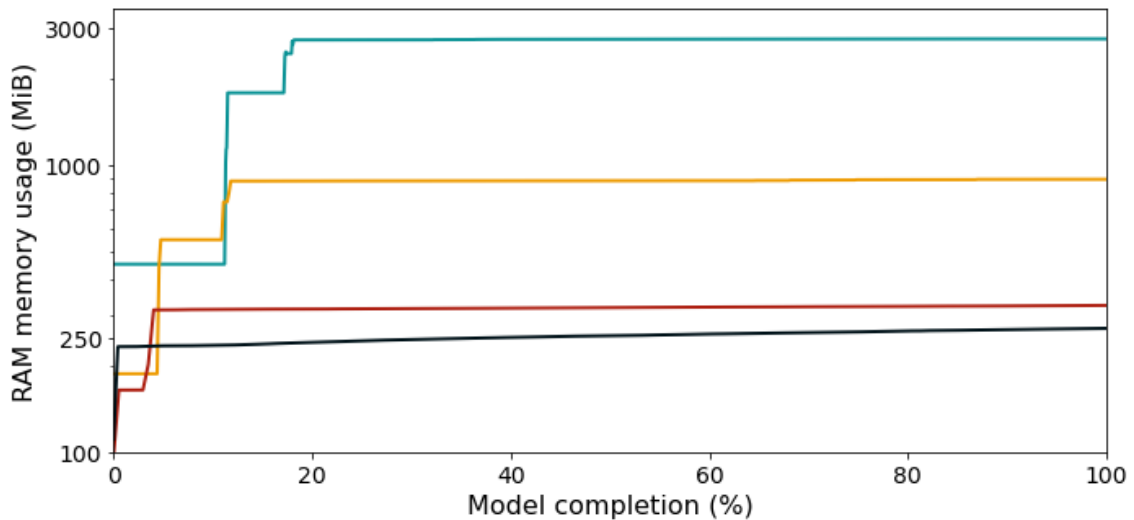
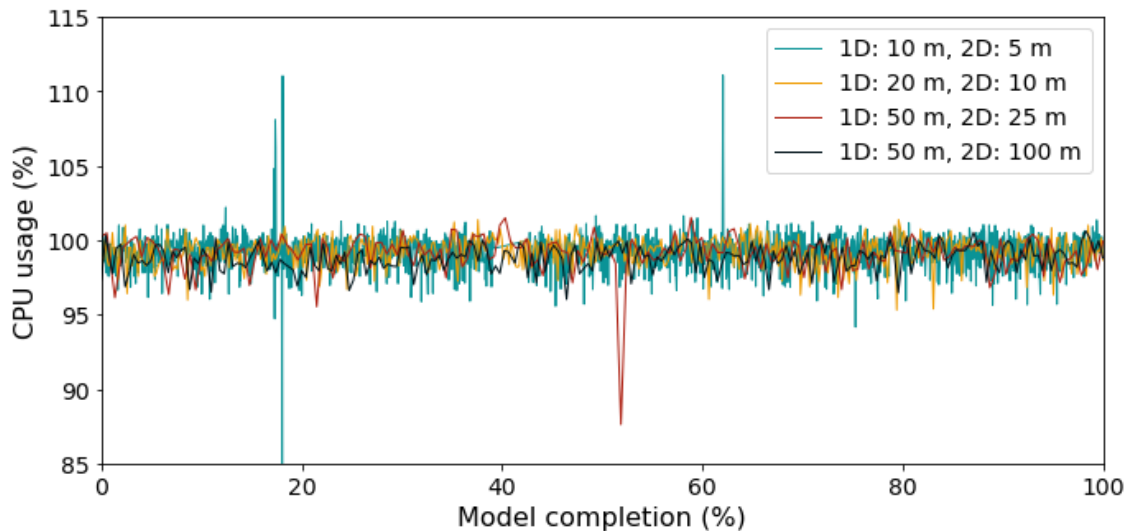






# Hardware gebruik

- Belangrijk om VMs te bepalen
- Model varianten
- CPU gebruik: 100%
- RAM gebruik: afhankelijk van resolutie



# HydroLogic

The background is a complex digital interface composed of a grid of rectangular panels. Each panel displays different types of data visualizations, including maps, network graphs, charts, and abstract patterns. The overall color scheme is dark blue and black, with bright white and light blue highlights. The panels are arranged in a way that creates a sense of depth and perspective, receding into the distance on the right side of the image.

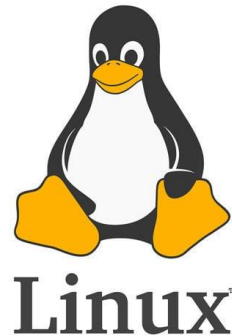
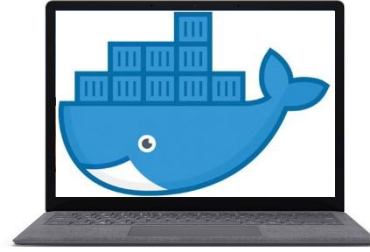
Cloud computing



# Cloud computing

*D-HYDRO* → *cloud*

- Cluster (Azure)
- Cloud storage
- Container
  - hierin is D-HYDRO geïnstalleerd
  - D-HYDRO container van Deltares
  - momenteel beta versie
- Linux
  - hoofdletter gevoelig
    - `flowmap.nc` of `FlowMap.nc`



# Cloud computing

## *Workflow*

- Doel workflow
  - automatische probabilistische inundatie voorspelling
  - simulaties gelijktijdig uitvoeren
    - rekestijd verminderen
- Microsoft Azure





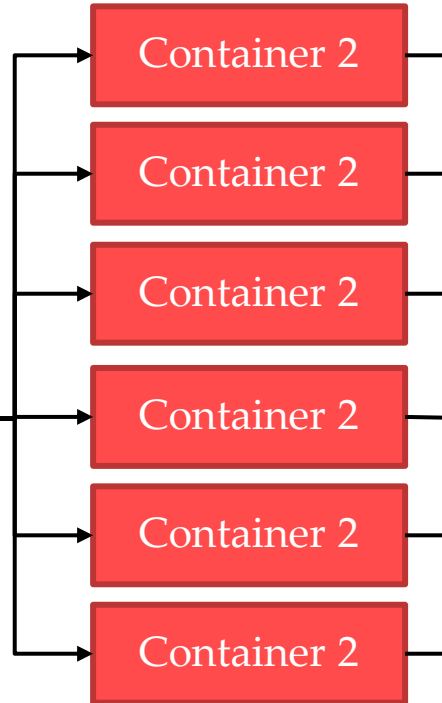
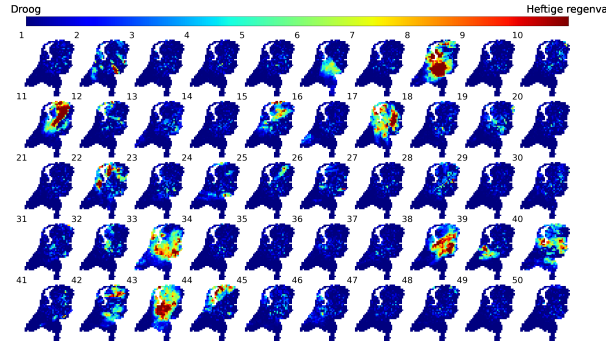
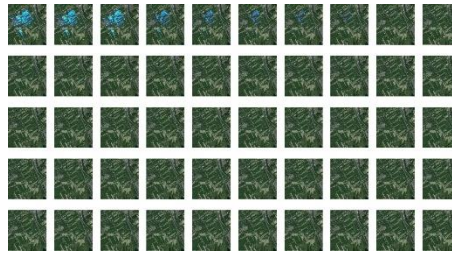
# Cloud computing

## *Workflow setup*

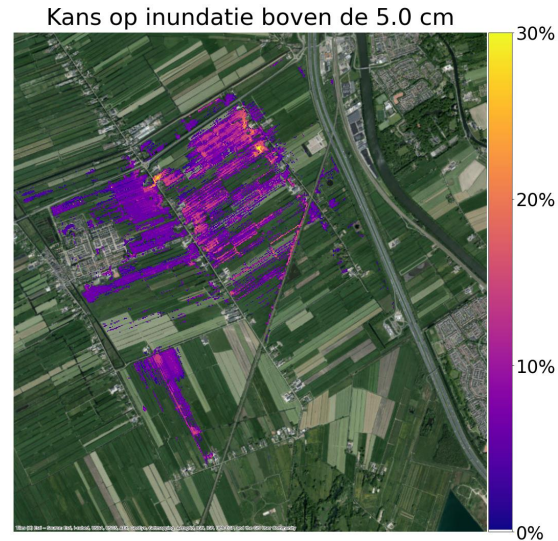
- 3 verschillende “containers”
- Container 1:
  - downloaden neerslag voorspellingen
  - klaarzetten tot model input voor alle simulaties
- Container 2:
  - parallel D-HYDRO simulaties uitvoeren
- Container 3:
  - nabewerking en visualisatie



# Cloud computing Workflow setup

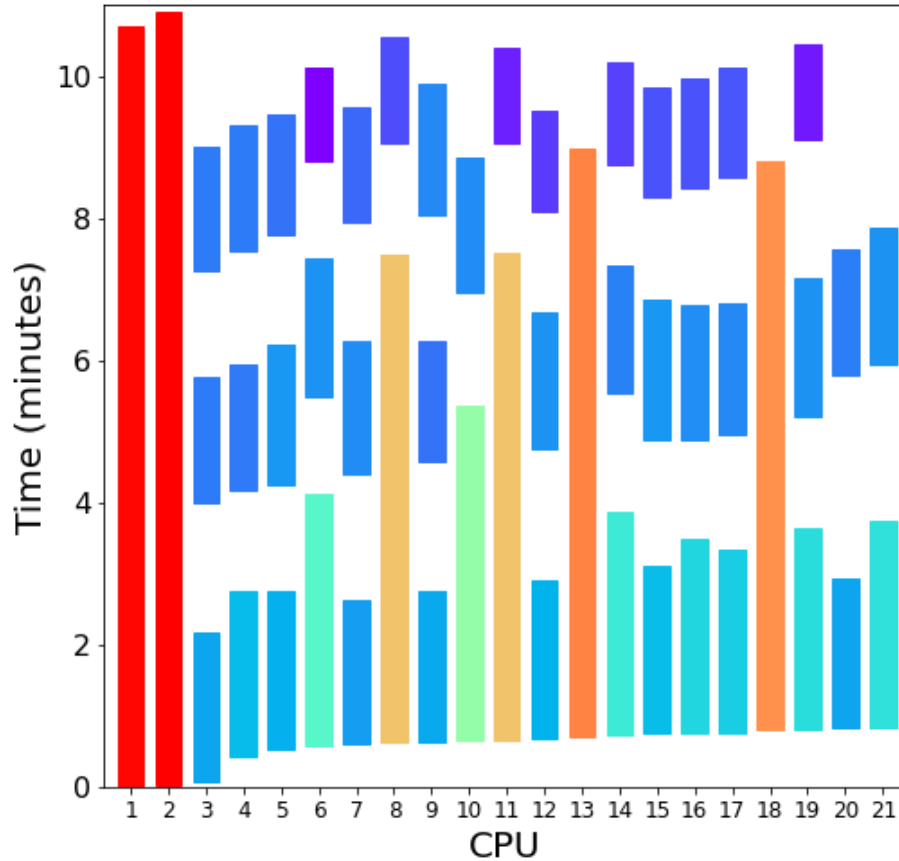


... x50





# 50 simulaties tegelijk?



# Cloud computing

## *Virtual Machine setup*

- Tests voor beste virtual machine setup
- Uitvoeren van één ensemble forecast
  - 50 ensemble members -> 50 simulaties
- Performance
  - rekestijd
  - kosten



# Cloud computing

## *Conclusie*

- Voor deze case study:
  - 50 modelsommen
    - normaal 5-15 minuten per modelsom
  - in 15 minuten
  - 0.40 euro per volledige forecast
- Probabilistische ensemble voorspelling
  - in de tijd van één simulatie
  - goedkoop
    - afhankelijk van rekestijd model





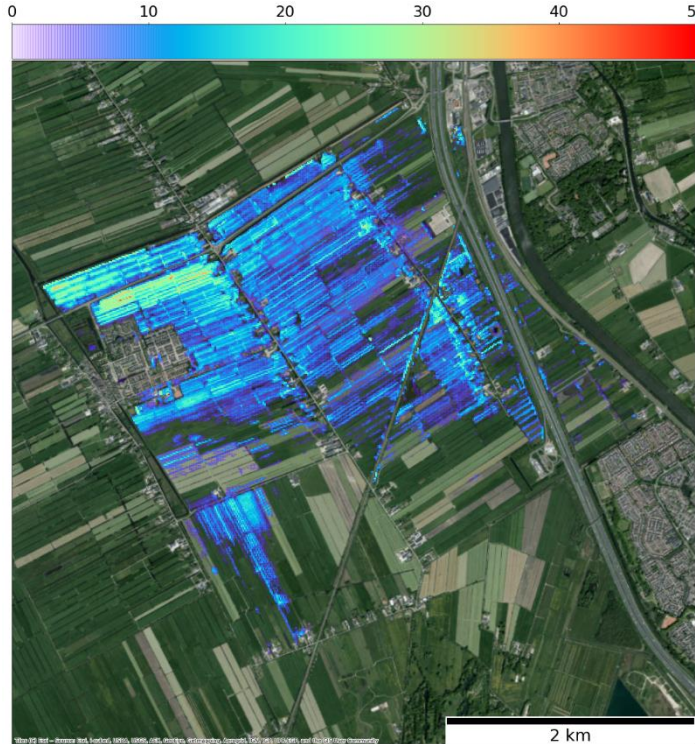
# HydroLogic



Neurale netwerk

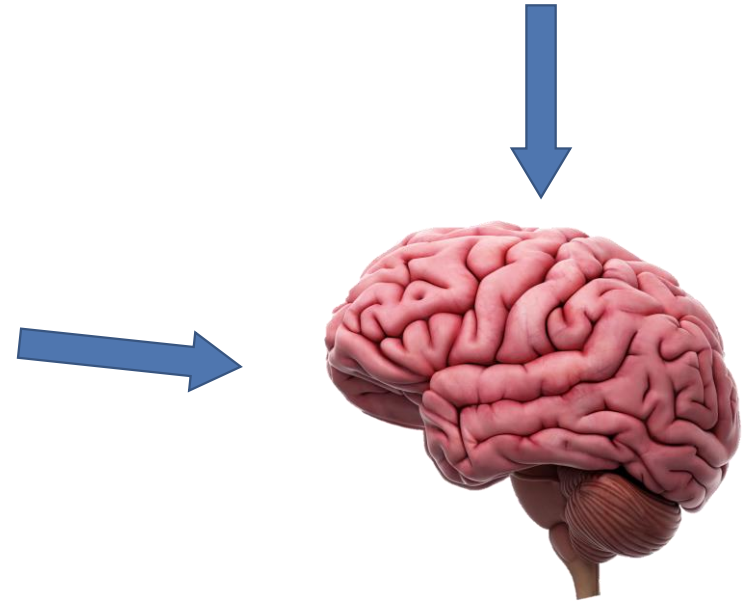
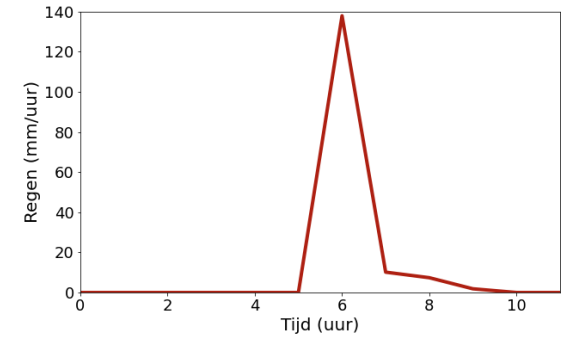
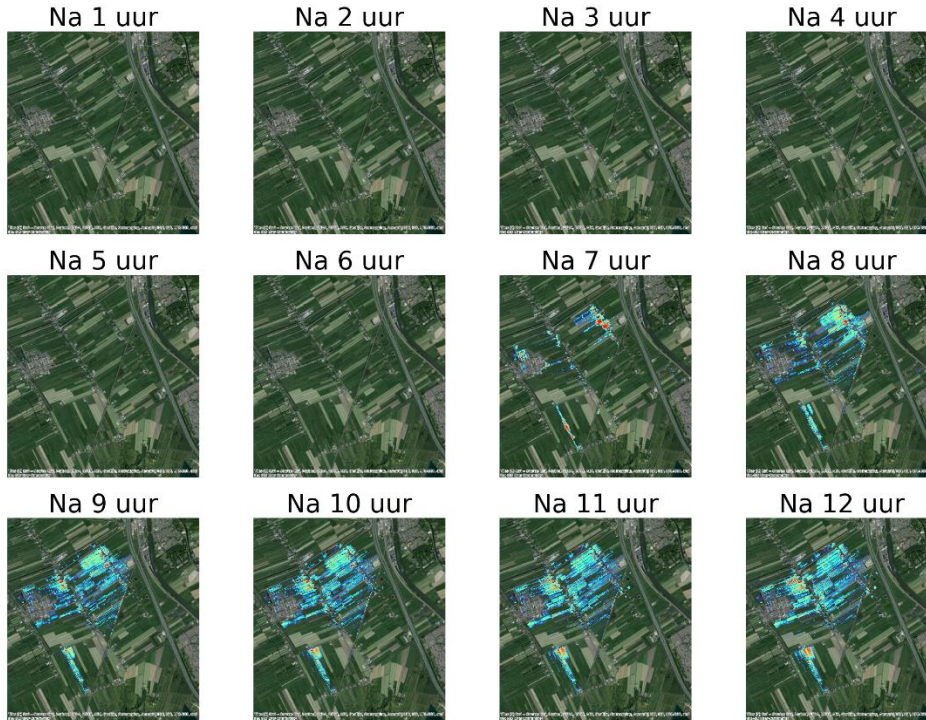
# Neurale netwerk

- Inundatie voorspellen op basis van neerslag
- Voor elke grid cel die inundeert
  - 53.381 cellen
- Op 12 tijdstappen
  - 1 stap = 1 uur
- Dus in totaal:
  - $53.381 * 12 =$
  - 640.572 outputs





# Voorbeeld





# Voorbeeld

Na 1 uur



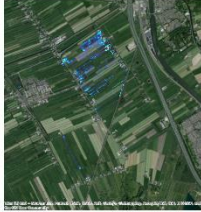
Na 2 uur



Na 3 uur



Na 4 uur



Na 5 uur



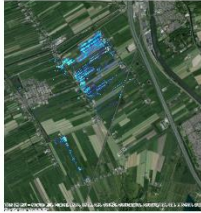
Na 6 uur



Na 7 uur



Na 8 uur



Na 9 uur



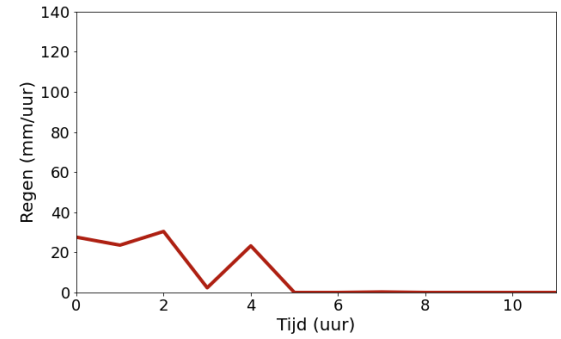
Na 10 uur



Na 11 uur



Na 12 uur



# Voorbeeld

Na 1 uur



Na 2 uur



Na 3 uur



Na 4 uur



Na 5 uur



Na 6 uur



Na 7 uur



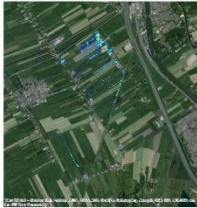
Na 8 uur



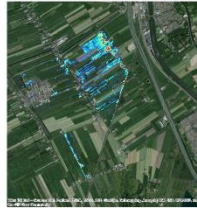
Na 9 uur



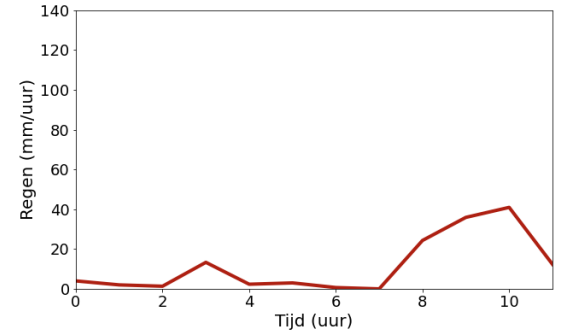
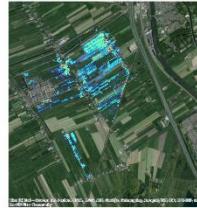
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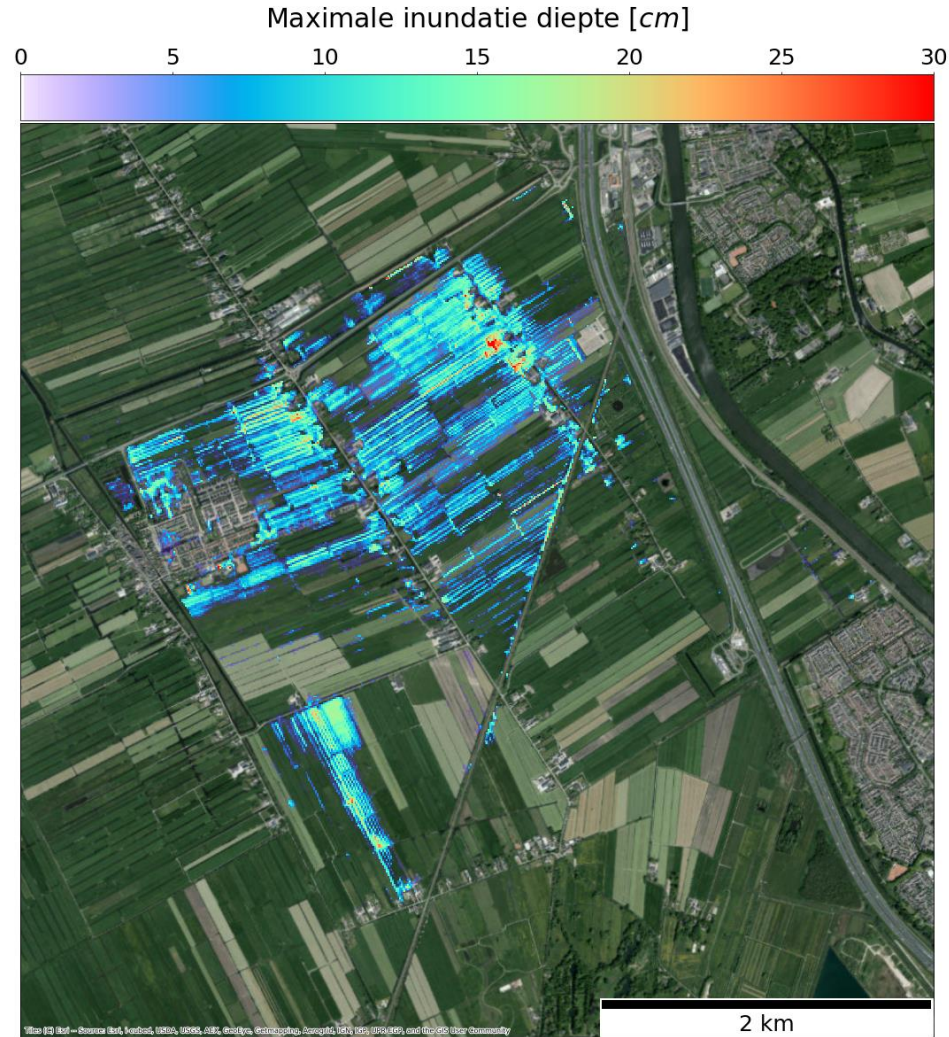
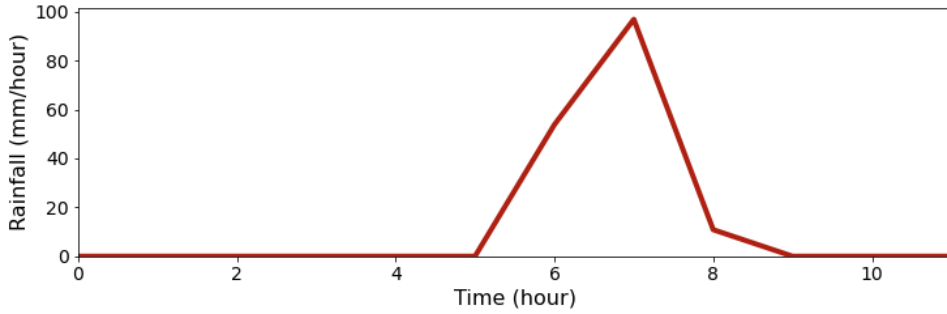
# Neurale netwerk

- Leren op basis van voorbeelden
- 2000 simulaties
  - gemaakt met cloud computing
  - ongeveer 25 euro
- Getrained op 1600 simulaties
  - andere 400 voor testen
- Optimalisatie van netwerk architectuur

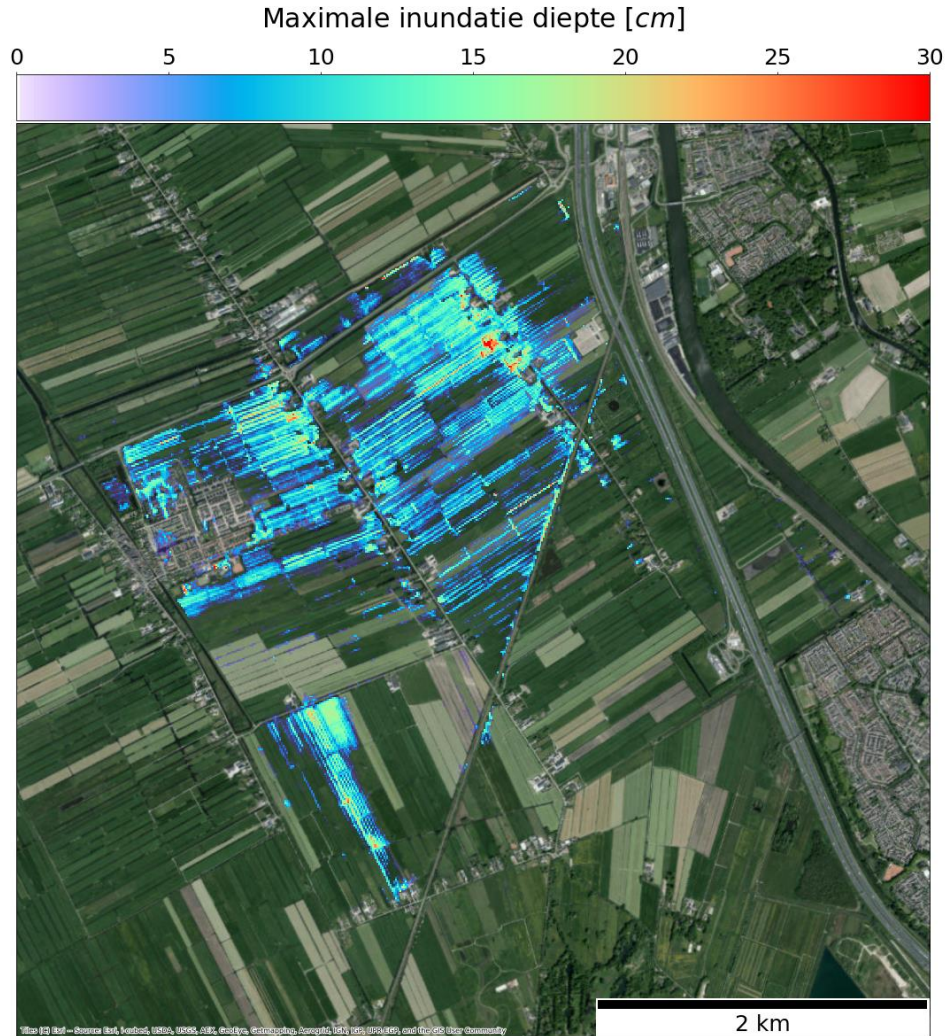
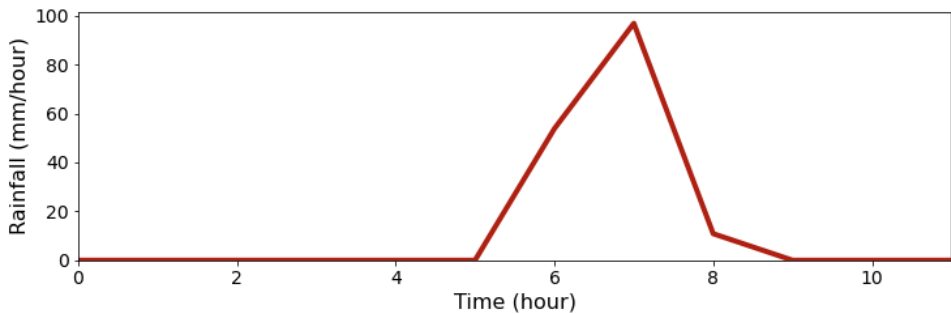




# D-HYDRO

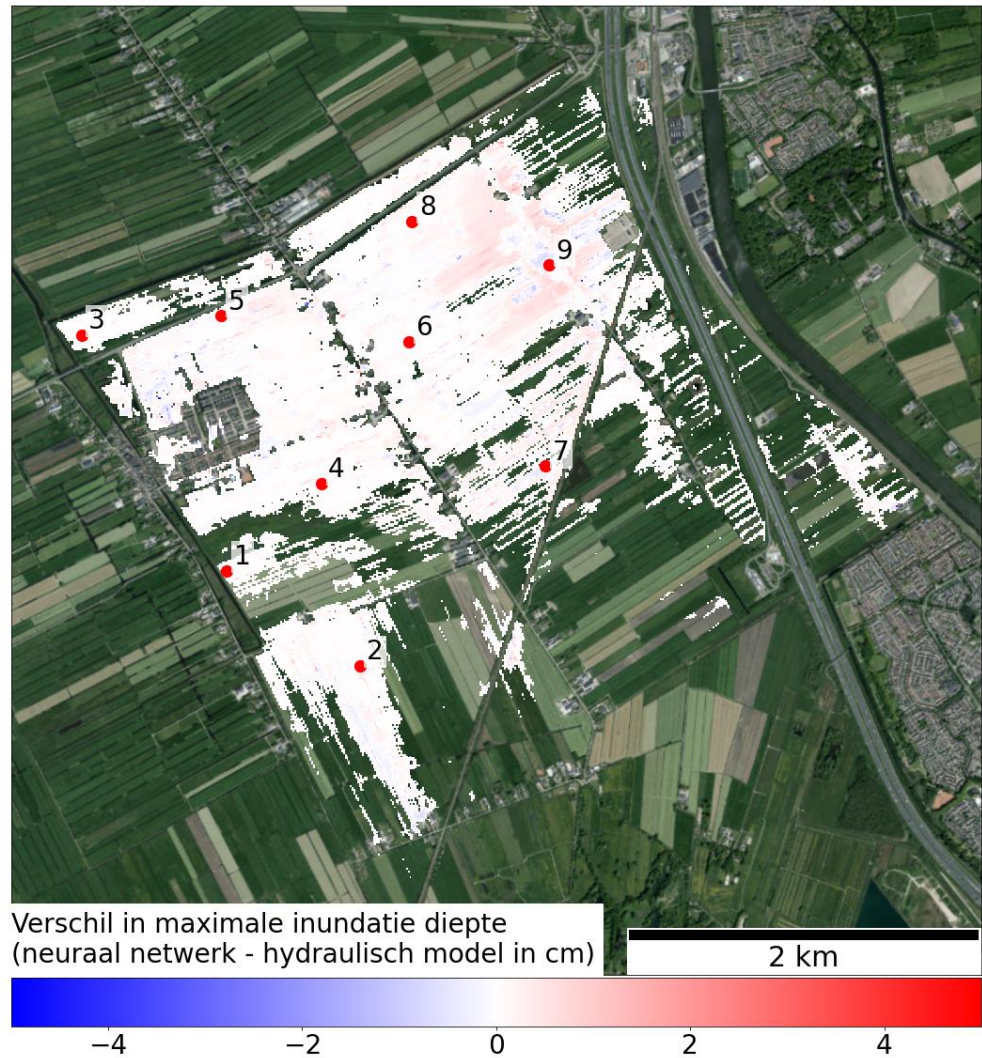
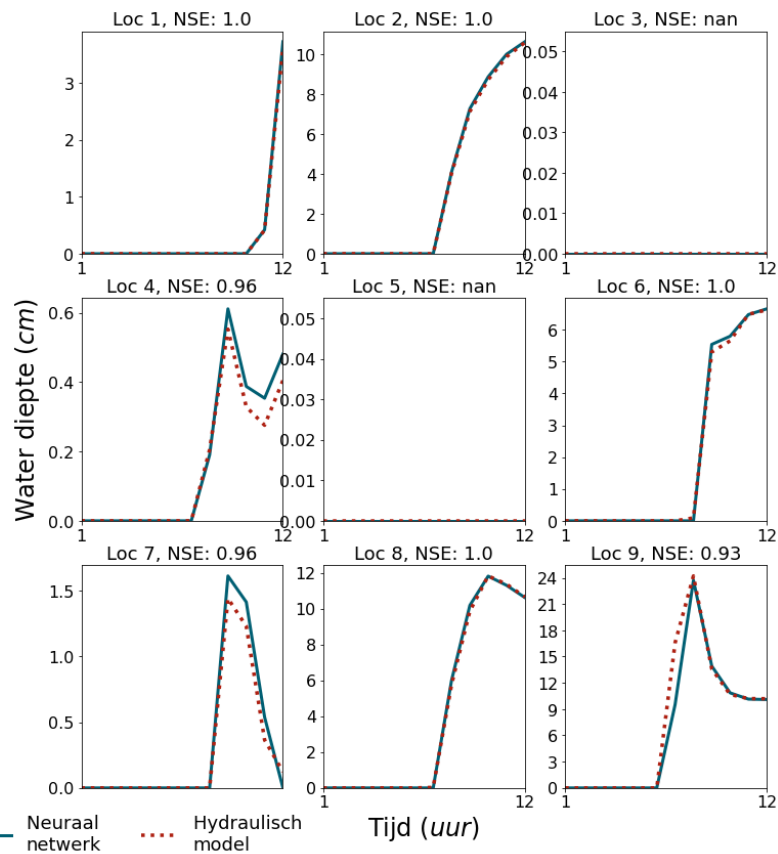


# Neurale netwerk



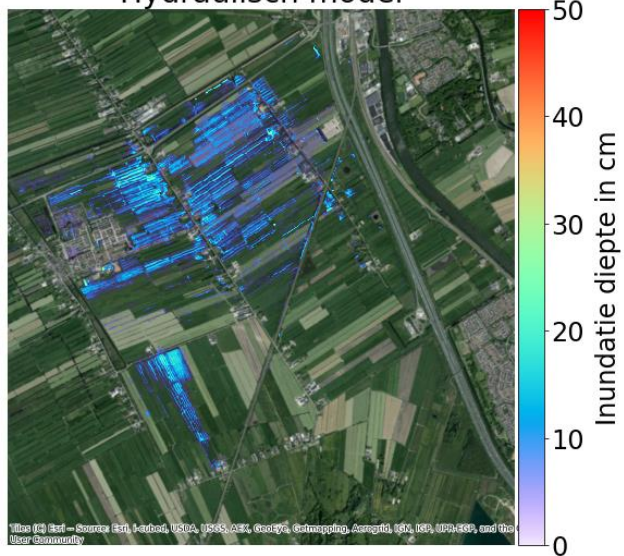


# Vershil

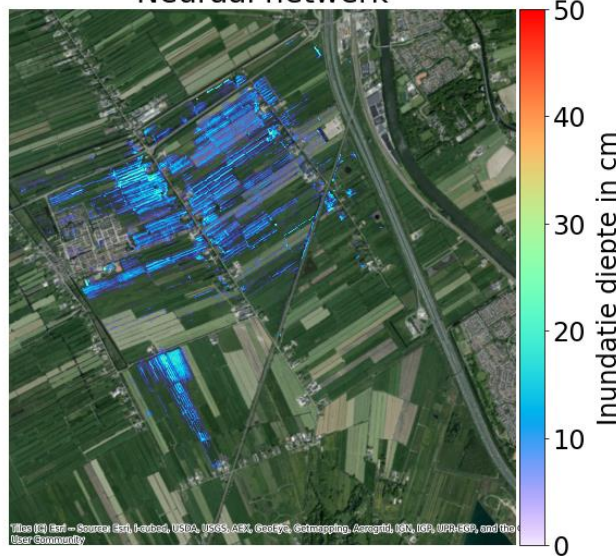




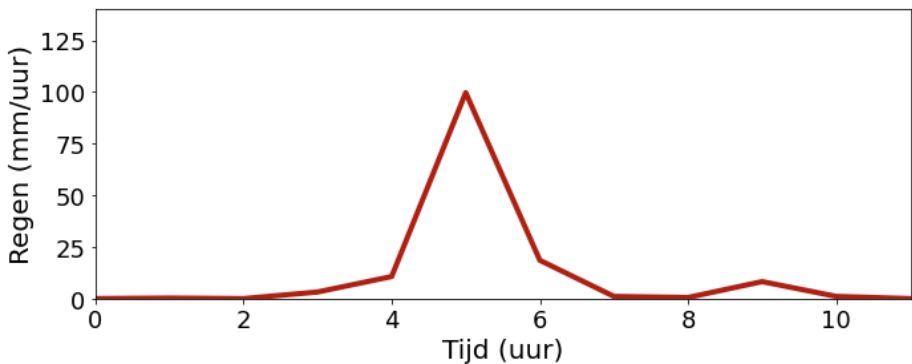
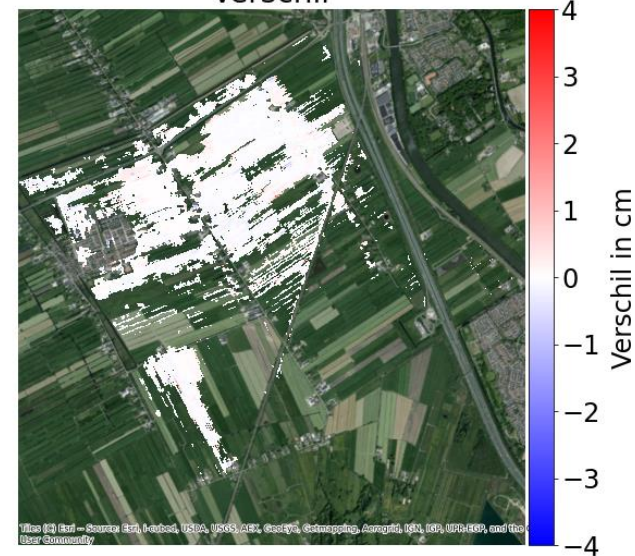
Hydraulisch model



Neuraal netwerk

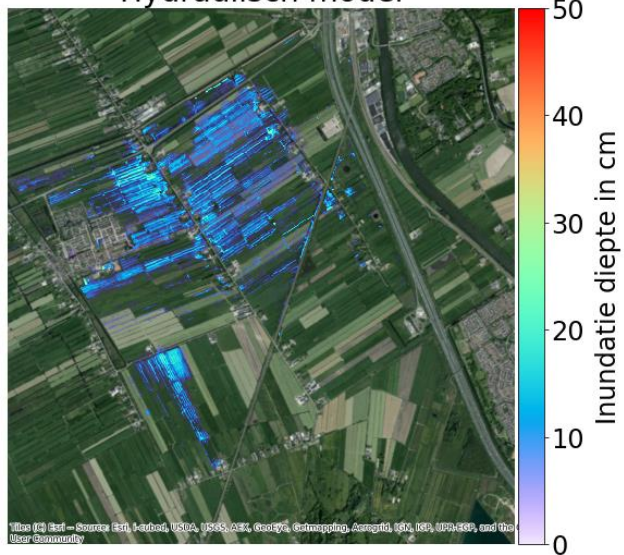


Vershil

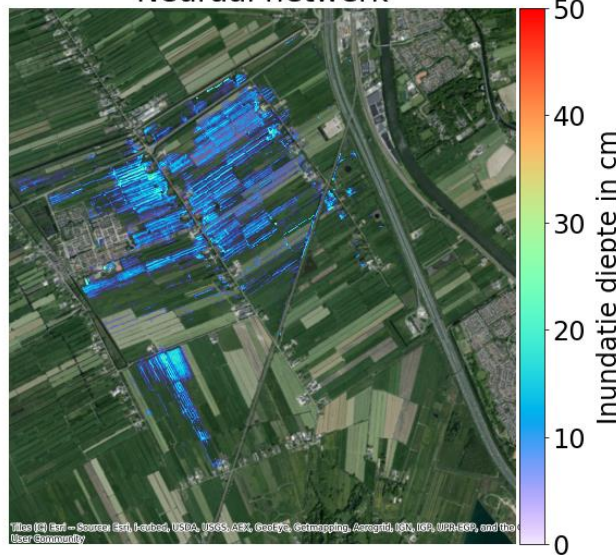


Willekeurige buien

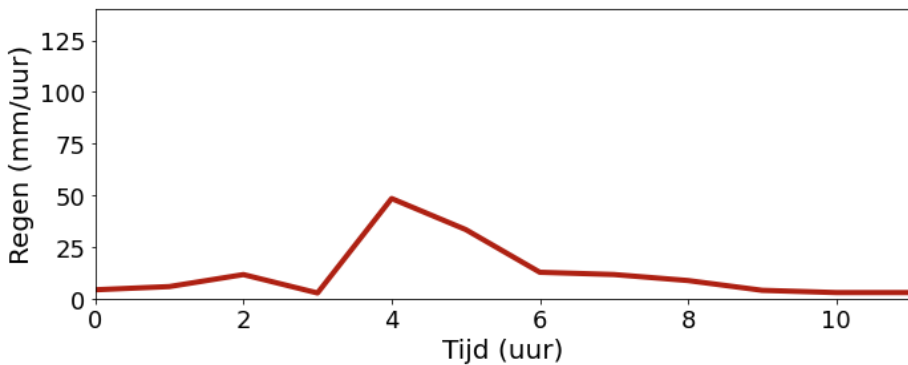
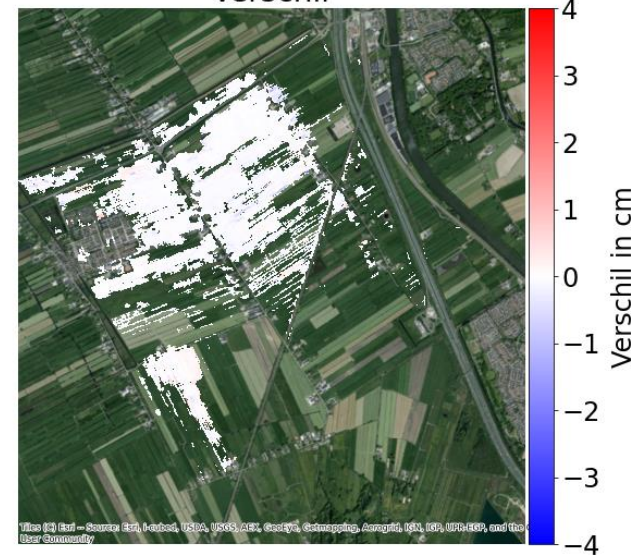
Hydraulisch model



Neuraal netwerk



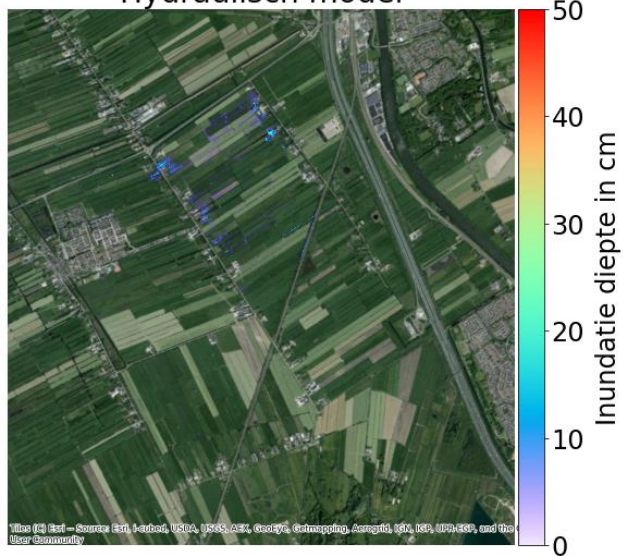
Vershil



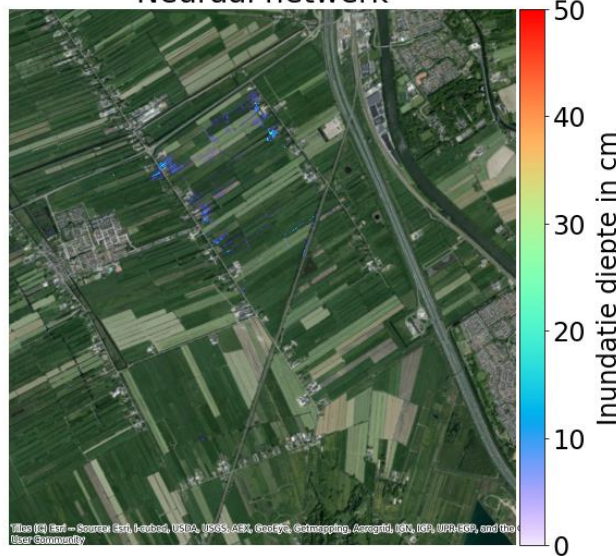
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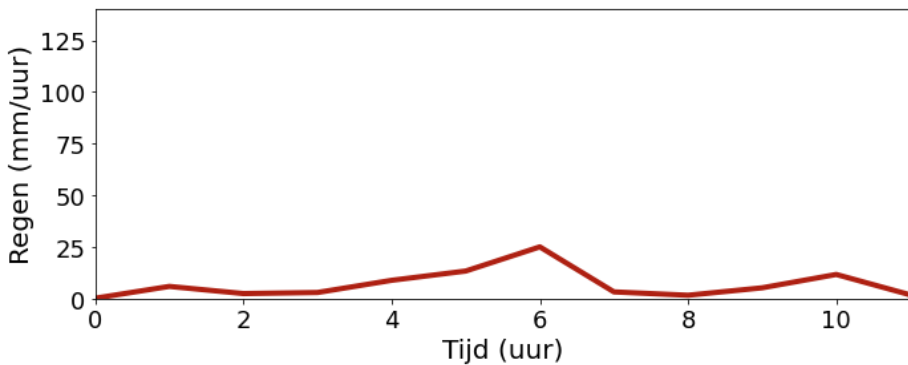
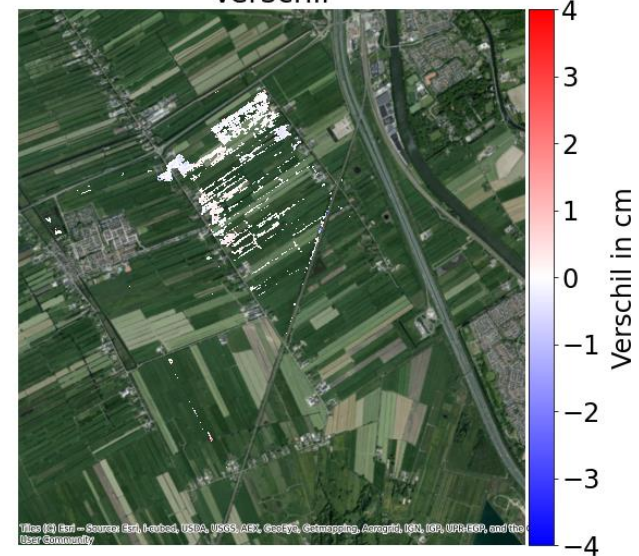
Hydraulisch model



Neuraal netwerk



Vershil



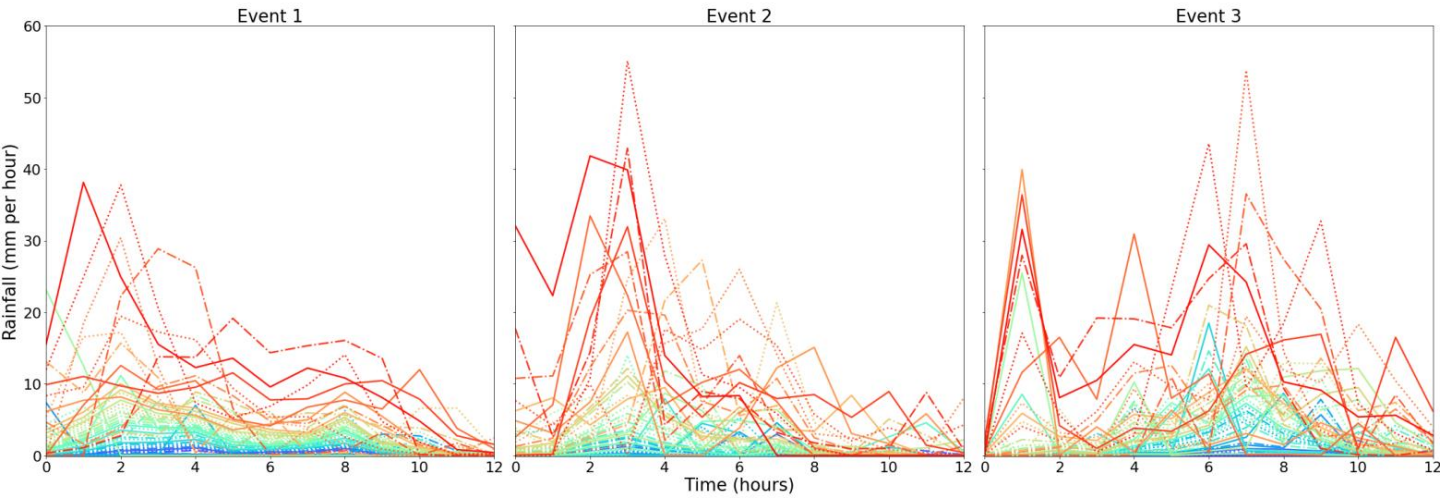
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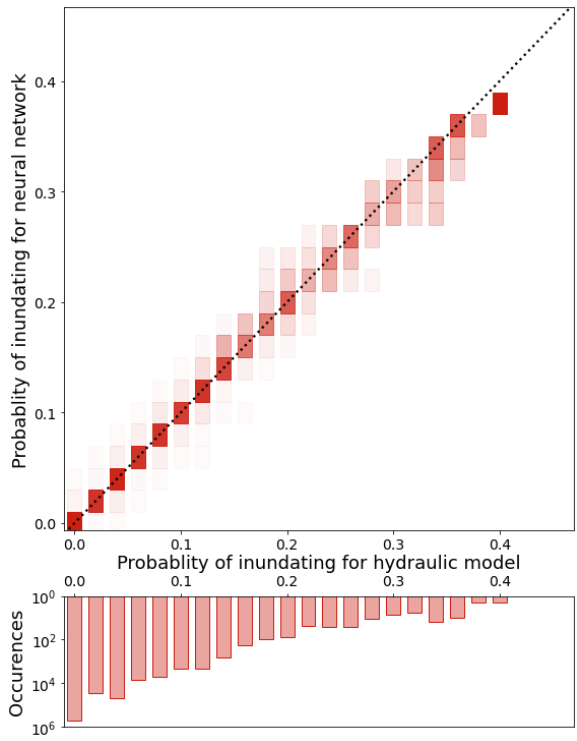


# Probabilistische voorspellingen

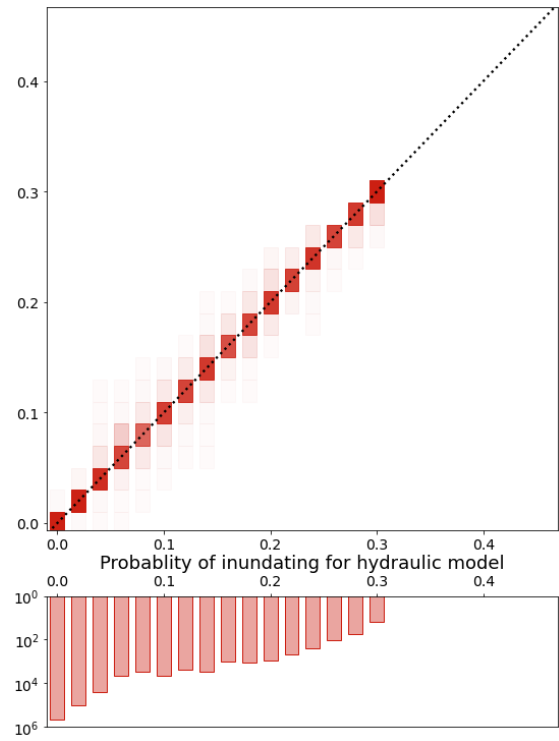
- 50 ensemble members
- Kansen berekenen
  - inundatie boven 5 cm
  - Per grid cell



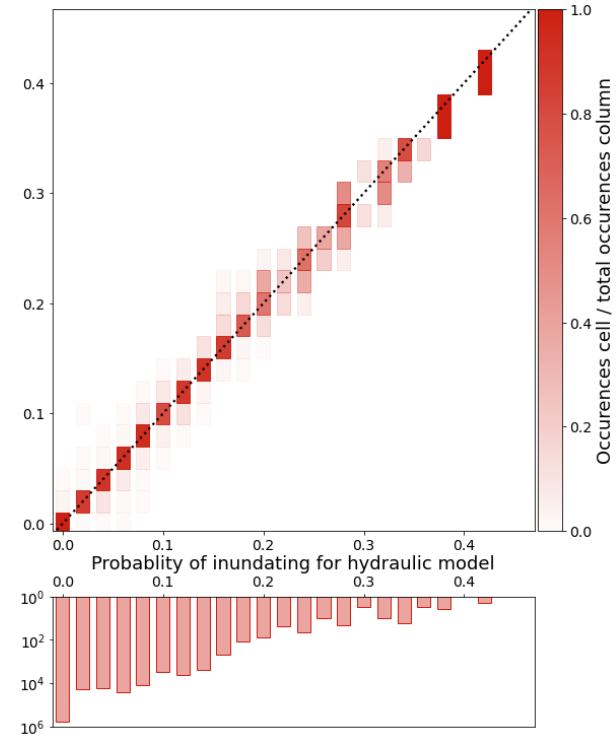
Event 1



Event 2



Event 3



- In 91% van gevallen: precies dezelfde kans als D-HYDRO model
- In 99.6% van gevallen: kans binnen 2% van D-HYDRO model



# Conclusie

- Cloud computing
  - probabilistische voorspelling in tijd van een deterministische
  - systeem voor automatische voorspellingen
  - operationeel inzetbaar
- Neuraal netwerk
  - kan D-HYDRO model goed “nadoen”
  - rekestijd 50 ensemble members < 1 seconde
  - real-time voorspellingen
- Wetenschappelijk artikel



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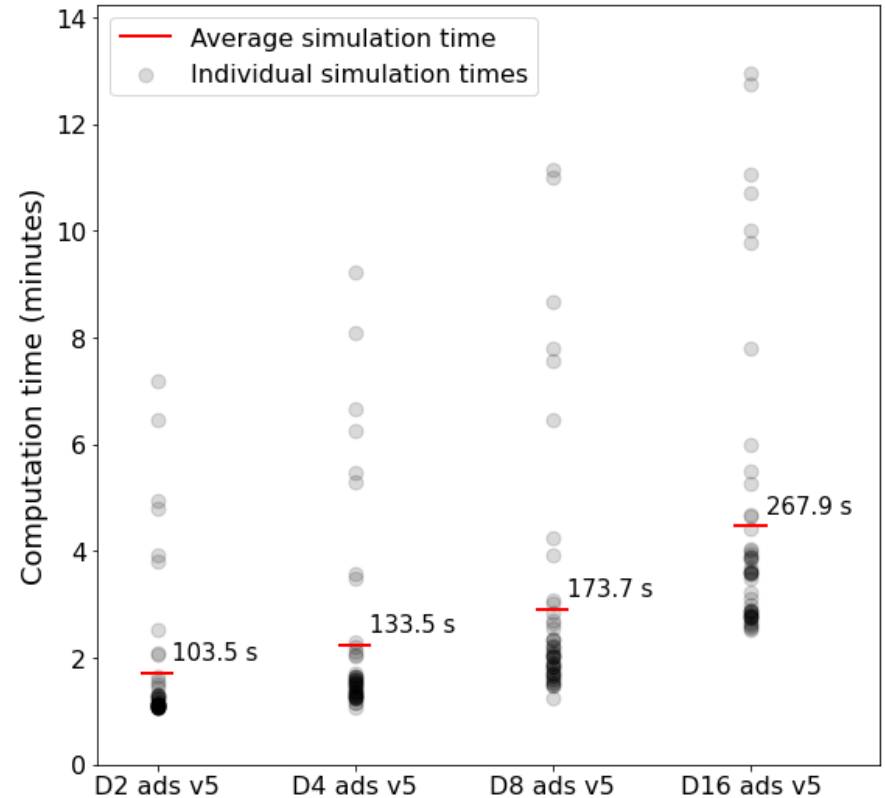
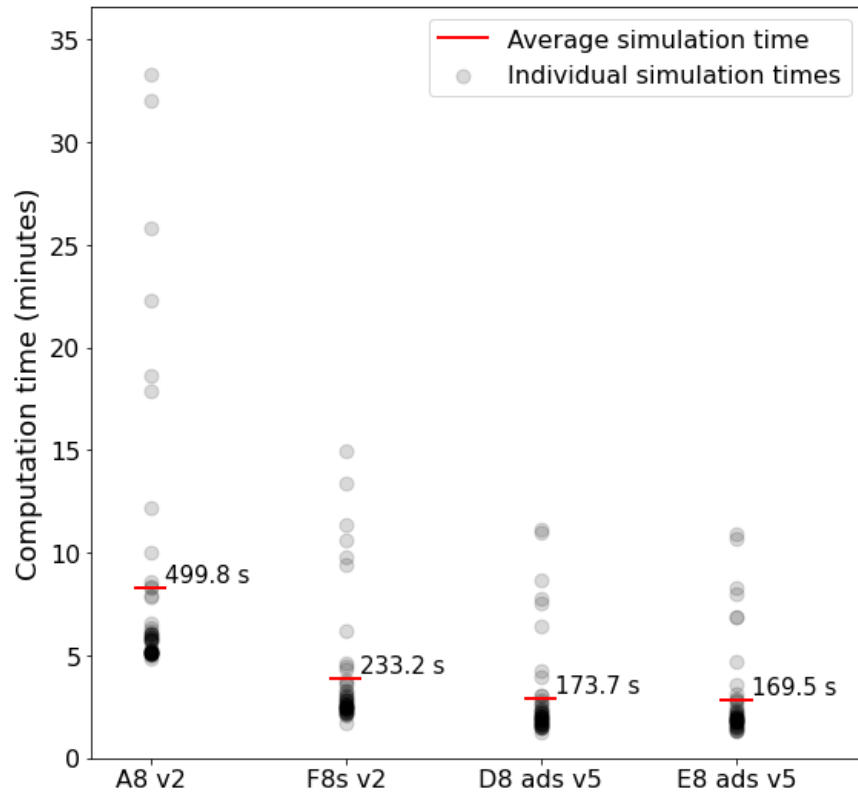
Name	Type	CPU's	RAM (GB)	Azure compute score	Cost (\$ per hour)	Average simulation time (s)	Simultaneous simulations	Total workflow time (mm:ss)	Total cost to complete workflow
A8 v2	General purpose	8	16	52.295	0.38	500	21	43:28	\$ 0,83
F8s v2	Compute optimized	8	16	136.027	0.39	233	21	20:51	\$ 0,41
D8 ads v5	General purpose	8	32	153.951	0.50	174	21	16:08	\$ 0,40
E8 ads v5	Memory optimized	8	64	153.765	0.63	170	21	15:22	\$ 0,49

Name	CPU's	RAM (GB)	Azure compute score	Cost (\$ per hour)	Machines hired	Average simulation time (s)	Simultaneous simulations	Total workflow time (mm:ss)	Total cost to complete workflow
D2 ads v5	2	8	38.919	0.13	12	104	12	17:25	\$ 0,45
D4 ads v5	4	16	72.644	0.25	6	134	18	15:14	\$ 0,38
D8 ads v5	8	32	153.951	0.50	3	165	21	16:08	\$ 0,40
D16 ads v5	16	64	306.800	1.00	2	268	30	18:09	\$ 0.60



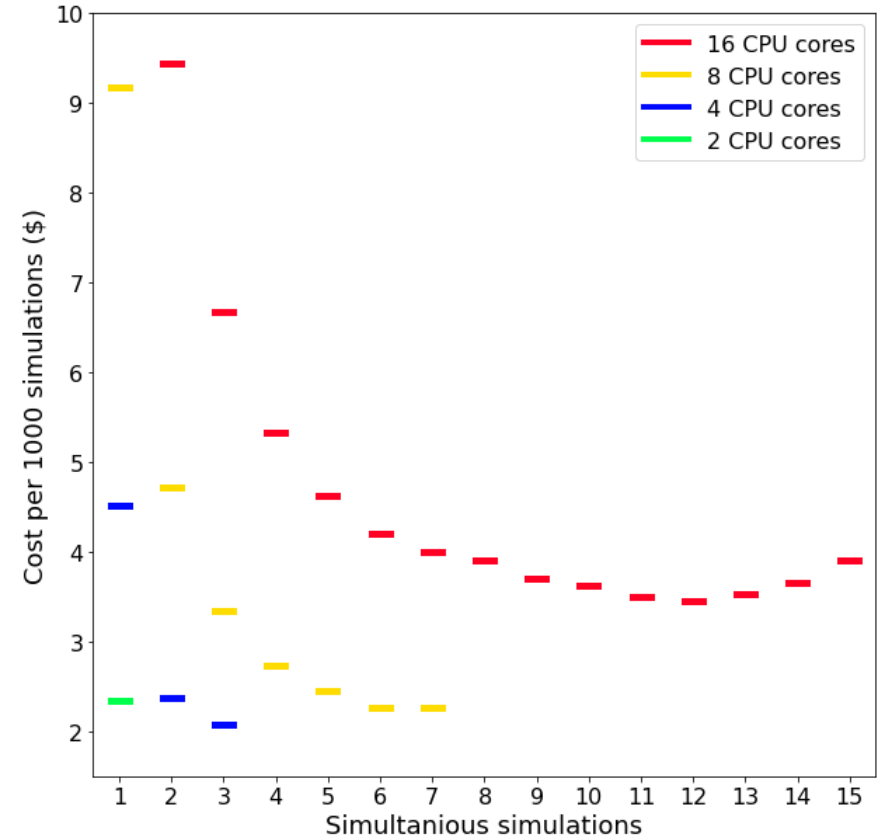
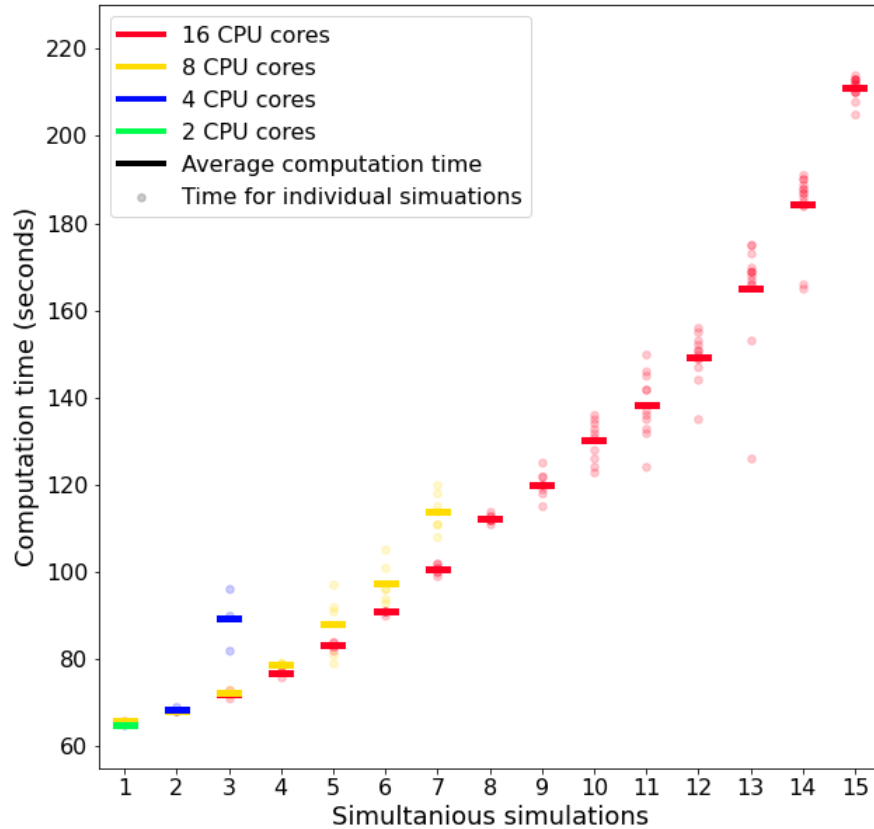
# Cloud computing

## *Virtual Machine setup: Resulaten*



# Cloud computing

## *Virtual Machine setup: Resultaten*



- **Verslag:**

[http://essay.utwente.nl/94319/1/Hop\\_MA\\_ET.pdf](http://essay.utwente.nl/94319/1/Hop_MA_ET.pdf)

- **Cloud workflow**

[https://github.com/HydroLogicBV/Cloud\\_Workflow\\_TKI\\_V](https://github.com/HydroLogicBV/Cloud_Workflow_TKI_V)

