TKI AI-kennis voor grondwaterverkenningen

Projectgroepoverleg 5 + scopingsessie
22 november 2023

HydroLogic

stowa STICHTING TOEGEPAST ONDERZOEK WATERBEHEER

HKV LIJN IN WATER

HOOGHEEMRAADSCHAP DE STICHTSE RIJNLANDEN

Witteveen + Bos

Waterschap Noorderzijlvest

Vitens

WATERSCHAP vechtstromen

WATERSCHAP ZUIDERZEELAND

Rijkswaterstaat
Ministerie van Infrastructuur en Waterstaat

Deltares

Agenda

1.	Opening + vaststellen agenda + mededelingen	09:30	- 09:35	(5 min)
2.	Notulen, acties, update projectplan n.a.v. vorig overleg	09:35	- 09:45	(10 min)
3.	Techniekontwikkeling: stand van zaken	09:45	- 10:45	(1 uur)
	koffie / thee	10:45	- 11:00	(15 min)
4.	Techniekontwikkeling: prioritering t/m februari 2024	11:00	- 11:35	(35 min)
5.	Planvorming in-kind uren-bestedingen	11:35	- 11:50	(15 min)
6.	Afspraken en volgend projectgroepoverleg	11:50	- 11:55	(5 min)
7.	Rondvraag en afsluiting	11:55	- 12:00	(5 min)
	Lunch	12:00	- 13:00	(1 uur)

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1. Opening, vaststellen agenda, mededelingen

Afmeldingen:

- Jacques Peerboom, RWS
- Jelle van Sijl, Vitens
- Romee van Dam, Deltares
- Rudolf Versteeg, Waterschap Zuiderzeeland
- Sjon Monincx, Waterschap Vechtstromen
- Rob van den Hengel verwacht een uur later te komen

Mededelingen:

- Nieuw teamlid Hydrologic: Carien Leushuis
- Nieuw teamlid Vitens: Anouk Sprong

- Sharepoint-omgeving, folder ‘Documenten’:
  - SOK
  - Projectplan
  - Invul-excel voor in-kind uren,
    vanaf nu maandelijks realisatie invullen a.u.b.

Response = ‘*None*’ in Outlook:

- Jannes
- Ron
- Thomas

Aanmeldingen Hands-on machine learing cursus:

- Anneloes Noordhoff, HydroLogic
- Anouk Sprong, Vitens
- Carien Leushuis, HydroLogic
- Jan Dirk Smidt, Witteveen+Bos
- Niels de Graaf, Waterschap Vechtstromen
- Panos Mavritsakis, Deltares
- Rob van den Hengel, HDSR
- Saskia van Brenk, Vitens
- Wilbert Berendrecht, Deltares
- Ysbrand Galama, Rijkswaterstaat

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2. Notulen, acties, update projectplan n.a.v. vorig overleg

- Verslag vorig overleg (d.d. 13-09-2023)

Actielijst

Volgnr	Actie	Naam	Vervaldatum
1	Beschrijving RWS-casus opnemen in projectplan	Bennie	15 nov 2023
2	Ronsturen manier om remote uren aan te geven	Bennie	15 nov 2023
3	Uitnodiging mini cursus sturen	Jonathan	22 sep 2023
4	Input voorbeelden voor rekenbudget	Panos en Jonathan	15 nov 2023
5	Datumprikken voor technical team	Jonathan	22 sep 2023
6	Nagaan of cursus online beschikbaar is	Jonathan	22 sep 2023

2. Notulen, acties, update projectplan n.a.v. vorig overleg

- Verslag vorig overleg (d.d. 13-09-2023)

2.3.2 Real-world casussen

Onderstaand een overzicht van de cases met een beknopte beschrijving van de ideeën zoals gedefinieerd door de casushouder.

Casus Rijkswaterstaat

- De casus richt zich op het zoeken naar een nieuwe vorm van stuwpeilbeheer t.b.v. maximale bevaarbaarheid van de Maas tijdens droge perioden. Invoervariabele daarbij is een verhoging van het stuwpeil (liefst per stuwpand), uitvoervariabelen zijn 1) flux(veranderingen) vanuit het grondwater naar de Maas, 2) flux(veranderingen) vanuit het grondwater naar de hoofdbeken en 3) verandering in GxG's in de direct omgeving van de beek. Aanpak: een gedeelte van het LHM clippen en gebruiken als testmodel.
- Identificatie van generieke AI-aspecten die inzetbaar kunnen zijn voor andere domeinen dan grondwater; bijbehorende workshop binnen Rijkswaterstaat.

Casus Vitens

- Uitvoeren van 'quick scans' als onderdeel van het zoeken naar potentiële nieuwe

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3. Techniekontwikkeling: stand van zaken

Input	Input type	Output effect		Output absolute			
		GXG effect	Head steady-state effect	Head series transient	Head prediction at T=t	Evaporation reduction	Flux (riv) effect
Moving well fixed Q	point	Vechtstromen	Vitens		HDSR		
Moving well varying Q	point		Vitens				
Kh value (kD-value)	raster		Vitens				
Kv value (c-value)	raster		Vitens				
Recharge (prec & evap)	series	Vitens?		HDSR, Vitens?	HDSR		
Drain elevation	raster	Vechtstromen					
River bottom elevation	raster	Vechtstromen	Vitens				
River bottom conductance	raster	Vechtstromen	Vitens				
River stage steady-state	raster	Vechtstromen; Zuiderzeeland (?)	Vitens		HDSR		
River stage transient	location; series or [start, period, strength]	RWS		Zuiderzeeland		Zuiderzeeland	Zuiderzeeland, RWS
River stage seasonal	2 rasters (or separate training summer / winter)	Vechtstromen				Zuiderzeeland	

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Moving well fixed Q	point	Vechtstromen	Vitens		HDSR		
Moving well varying Q	point		Vitens				
Kh value (kD-value)							
Kv value (c-value)							
Recharge (prec & eva				Vitens?	HDSR		
Drain elevation							
River bottom elevation							
River bottom conducta							
River stage steady-sta					HDSR		
River stage transient				eeland		Zuiderzeeland	Zuiderzeeland, RWS
River stage seasonal						Zuiderzeeland	

Moving well – steady-state

- Simplified Vitens model 256x256 -> 64x64
- Trained on drawdown instead of head
- Tested: DON, FNO, GAN, Unet
- Different loss functions
- Different sampling for DON. Sampling around the well, using Laplace-points => greater detail
- Potential spend more time on FNO
- Tried to optimize the layer-network (hyperparameters), mainly DON, some UNet
- **DON wins for now, FNOs can have more attention**

3. Techniekontwikkeling: stand van zaken

Input	Input type	Output effect		Output absolute			
		GXG effect	Head steady-state effect	Head series transient	Head prediction at T=t	Evaporation reduction	Flux (riv) effect
Moving well fixed Q	point	Vechtstromen	Vitens		HDSR		
Moving well varying Q	point		Vitens				
Kh value (kD-value)	raster		Vitens				
Kv value (c-value)							
Recharge (prec & e				R, Vitens?	HDSR		
Drain elevation							
River bottom elevati							
River bottom condu							
River stage steady-s					HDSR		
River stage transien				erzeeland		Zuiderzeeland	Zuiderzeeland, RWS
River stage seasonal	2 rasters (or separate training summer / winter)	Vechtstromen				Zuiderzeeland	

Moving well – steady-state

- Simplified Vitens model 64x64
- Trained on drawdown instead of head
- Tested: DON, FNO, GAN, Unet
- Tried them all, but in less detail
- Focused more on DON and Unet
- **DON wins for now, FNOs can have more attention**

3. Techniekontwikkeling: stand van zaken

Input	Input type	Output effect		Output absolute			
		GXG effect	Head steady-state effect	Head series transient	Head prediction at T=t	Evaporation reduction	Flux (riv) effect
Moving well fixed Q	point	Vechtstromen	Vitens		HDSR		
Moving well varying Q	point		Vitens				
Kh value (kD-value)	raster		Vitens				
Kv value (c-value							
Recharge (prec &					SR		
Drain elevation							
River bottom elev							
River bottom con							
River stage stead					SR		
River stage transient	location; series or [start, period, strength]	RWS		Zuiderzeeland		Zuiderzeeland	Zuiderzeeland, RWS
River stage seasonal	2 rasters (or separate training summer / winter)	Vechtstromen				Zuiderzeeland	

Varying Kh value – steady-state

- Hypothetical model 1 (structured river pattern)
- Hypothetical model 4 (unstructured river pattern)
- Model dimensions: 256x128
- Tested: DON, FNO, GAN, Unet
- **DON wins, Unet + FNO close**

3. Techniekontwikkeling: stand van zaken

Input	Input type	Output effect		Output absolute			
		GXG effect	Head steady-state effect	Head series transient	Head prediction at T=t	Evaporation reduction	Flux (riv) effect
Moving well fixed Q	point	Vechtstromen	Vitens		HDSR		
Moving well varying Q	point						
Kh value (kD-value)	raster						
Kv value (c-value)	raster						
Recharge (prec & evap)	series						
Drain elevation	raster						
River bottom elevation	raster						
River bottom conductance	raster						
River stage steady-state	raster	Vechtstromen; Zuiderzeeland (?)	Vitens		HDSR		
River stage transient	location; series or [start, period, strength]	RWS		Zuiderzeeland		Zuiderzeeland	Zuiderzeeland, RWS
River stage seasonal	2 rasters (or separate training summer / winter)	Vechtstromen				Zuiderzeeland	

River stage – GXG effect

- Hypothetical model 6 (unstructured river pattern)
- Trained on stage change and GXG effect
- Model dimensions: 256x128
- Tested: DON, FNO, ~~GAN~~, Unet
- Initial test with simplified Vechtstromen model (256x256x10)
- **DON seems to win (visually)**

3. Techniekontwikkeling: stand van zaken

Recharge - Head prediction at T=t

- Hypothetical model 3 (unstructured river pattern)
- Model dimensions: 256x128
- Trained on
  - absolute heads
  - difference between predicted head and initial head
- Tested: LSTM encoder-decoder, Default DON, (sequential DON under construction)

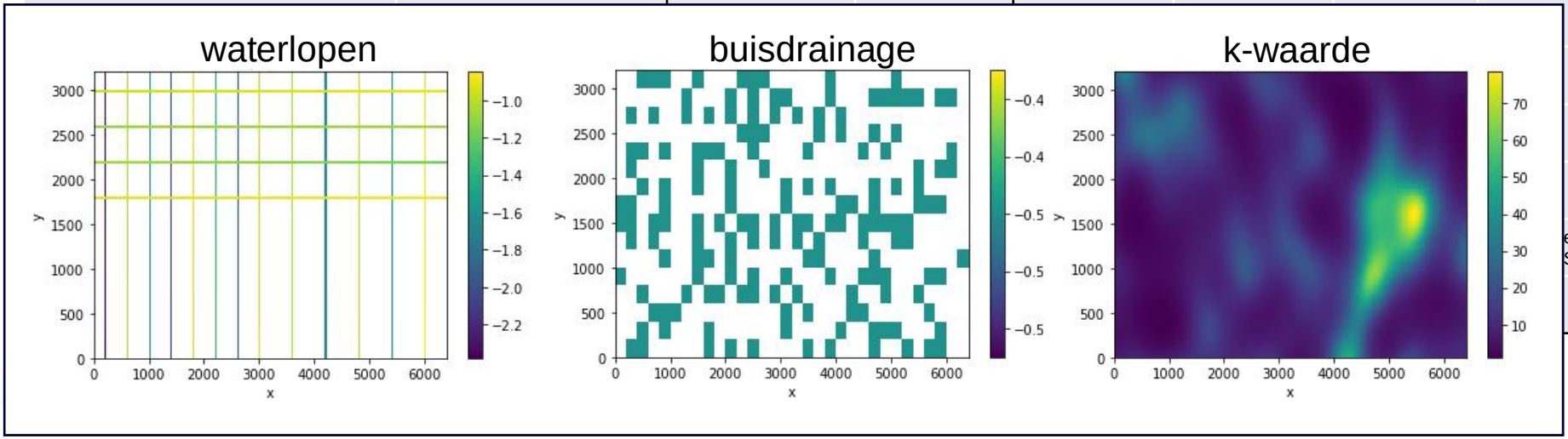
Input	Input type	Output effect		Output absolute			
					Head prediction at T=t	Evaporation reduction	Flux (riv) effect
					HDSR		
					HDSR		
River bottom elevation	raster	Vechtstromen	Vitens				
River bottom conductance	raster	Vechtstromen	Vitens				
River stage steady-state	raster	Vechtstromen; Zuiderzeeland (?)	Vitens		HDSR		
River stage transient	location; series or [start, period, strength]	RWS		Zuiderzeeland		Zuiderzeeland	Zuiderzeeland, RWS
River stage seasonal	2 rasters (or separate training summer / winter)	Vechtstromen				Zuiderzeeland	

3a. Onderliggende trainingsdata en modellen

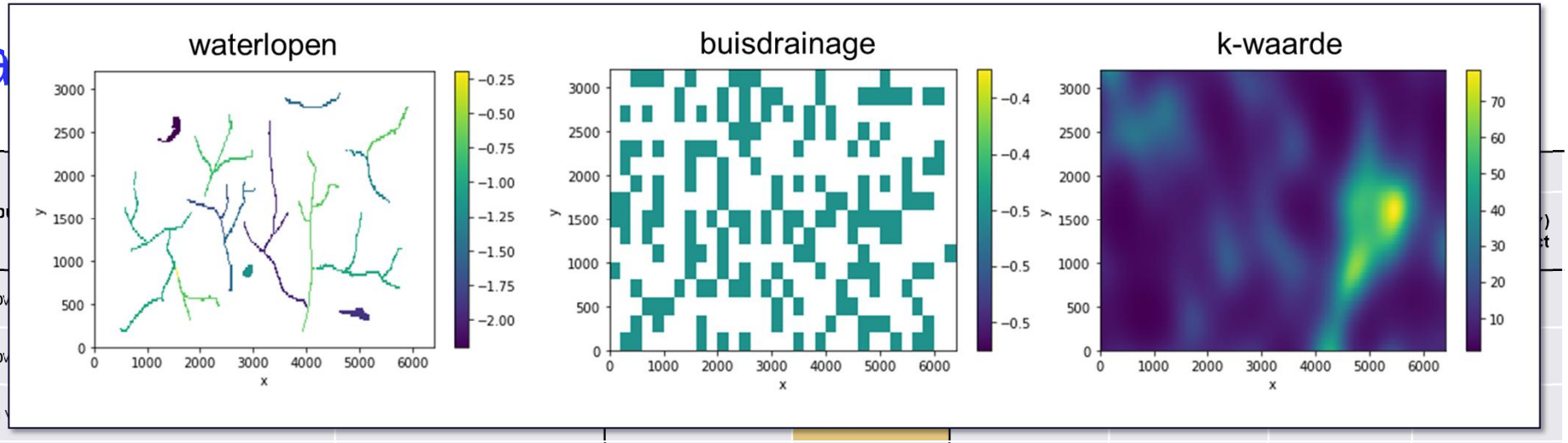
1. **Hypothetische MODFLOW-modellen**
   - inzichtelijk
   - klein (64x64 of 256x128, 1 modellaag)
   - “snel” verschillende input-output combinaties
   - Twee basismodellen ontwikkeld
2. **Vereenvoudigde MODFLOW-MetaSWAP-casusmodellen**
   - wat groter dan hypothetische modellen: 256x256, meerdere lagen
   - meer complexiteit
3. **Volledige casusmodellen (volgende fase)**

3a. Onderliggende trainingsdata en modellen

Input	Input type	Output effect		Output absolute			
		GXG effect	Head steady-state effect	Head series transient	Head prediction at T=t	Evaporation reduction	Flux (riv) effect
Moving well fixed Q	point	Vechtstromen	Vitens		HDSR		
Moving well varying Q	point		Vitens				
Kh value (kD-value)	raster		Vitens				
Kv value (c-value)	raster		Vitens				
Recharge (prec & evap)	series	Vitens?		HDSR, Vitens?	HDSR		



3a



Input							
Mov							
Mov							
Kh v							
Kv value (c-value)	raster		Vitens				
Recharge (prec & evap)	series	Vitens?		HDSR, Vitens?	HDSR		
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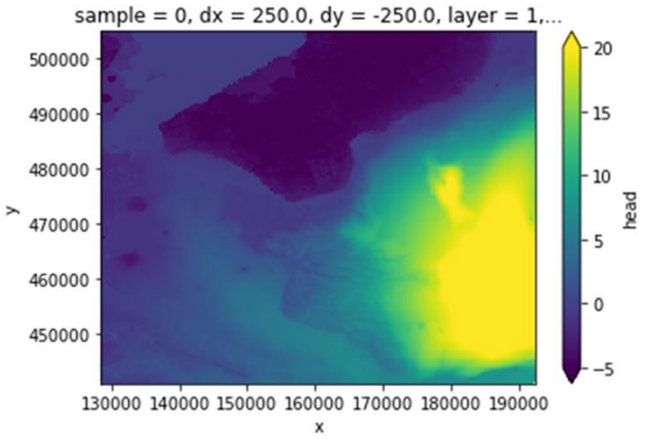
Moving well fixed Q	point	Vechtstromen	Vitens		HDSR		
Moving well varying Q	point		Vitens				
Kh value (kD-value)	raster		Vitens				
Kv valu							
Rechar							
Drain e							
River b							
River b							
River s							
River s							
River s	summer / winter)						

Vereenvoudigd Vitens model

- Uitsnede uit LHM (250 m resolutie)
- 256 x 256 x 8 → 64 x 64 x 8
- Stationaire berekening



3a. Onderliggende trainingsdata en modellen

Vereenvoudigde casusmodellen – vervolg:

- HDSR, Zuiderzeeland, Vechtstromen worden ook vereenvoudigd
- Uitsnede uit AZURE resp. MIPWA
- 256 x 256 x (9 / 10)

		Output effect		Output absolute			
Kv value (c-value)	raster		Vitens				
Recharge (prec & evap)	series	Vitens?		HDSR, Vitens?	HDSR		
Drain elevation	raster	Vechtstromen					
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River stage steady-state	raster	Vechtstromen; Zuiderzeeland (?)	Vitens		HDSR		
River stage transient	location; series or [start, period, strength]	RWS		Zuiderzeeland		Zuiderzeeland	Zuiderzeeland, RWS
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River stage steady-state	raster	Vechtstromen; Zuiderzeeland (?)	Vitens		HDSR		
River stage transient	location; series or [start, period, strength]	RWS		Zuiderzeeland		Zuiderzeeland	Zuiderzeeland, RWS
River stage seasonal	2 rasters (or separate training summer / winter)	Vechtstromen				Zuiderzeeland	

Wandelende winning

- Puntdata - x, y, laag, Q
- Random locatie en onttrekkingsdebiet (0.5 - 14 Mm3/j)

3a. Onderliggende trainingsdata en modellen

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Moving well varying Q	point						
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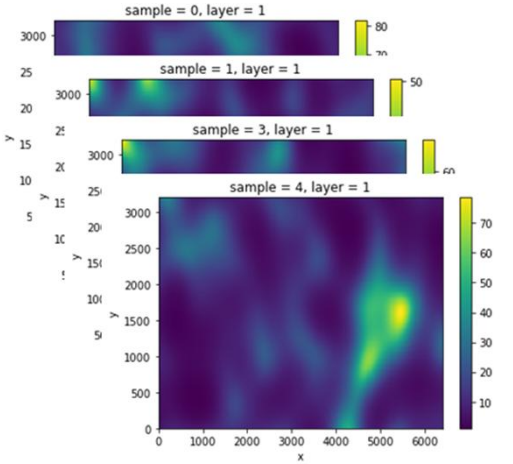
Kv value (c-value)	raster						
Recharge (prec & evap)	series						
Drain elevation	raster						
River bottom elevation	raster						
River bottom conductance	raster						
River stage steady-state	raster	Zuiderzeeland (?)					
River stage transient	location; series or [start, period, strength]	RWS		Zuiderzeeland		Zuiderzeeland	Zuiderzeeland, RWS
River stage seasonal	2 rasters (or separate training summer / winter)	Vechtstromen				Zuiderzeeland	

Kh-waarde

- 2D raster
- Random veld met vaste variantie en correlatielengte



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Moving well varying Q	point						
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Kv value (c-value)	raster						
Recharge (prec & evap)	series						
Drain elevation	raster						
River bottom elevation	raster						
River bottom conductance	raster						
River stage steady-state	raster	Zuiderzeeland (?)					
River stage transient	location; series or [start, period, strength]	RWS		Zuiderzeeland		Zuiderzeeland	Zuiderzeeland, RWS
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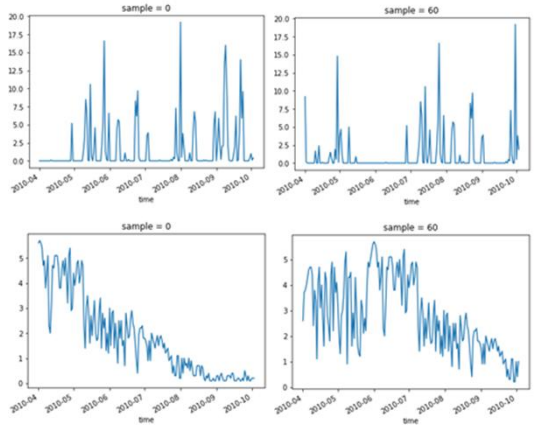
Recharge

- Tijdreeksen van neerslag en verdamping
- Samples uit historische KNMI reeks



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Moving well varying Q	point						
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Recharge (prec & evap)	series						
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River stage steady-state	raster	Zuiderzeeland (?)					
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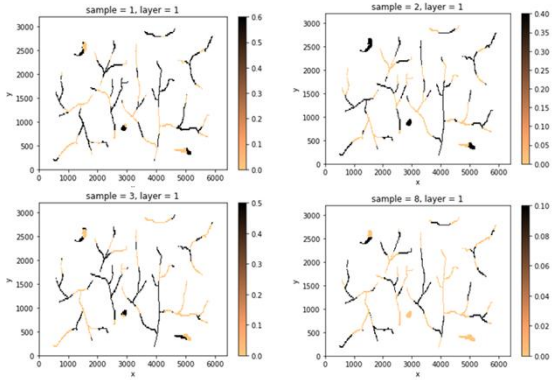
River stage

- 2D raster
- Binair random veld (wel/geen peilverhoging)
- Variatie in correlatielengte
- Uniforme waarde peilverhoging
- Onderscheid type watergang



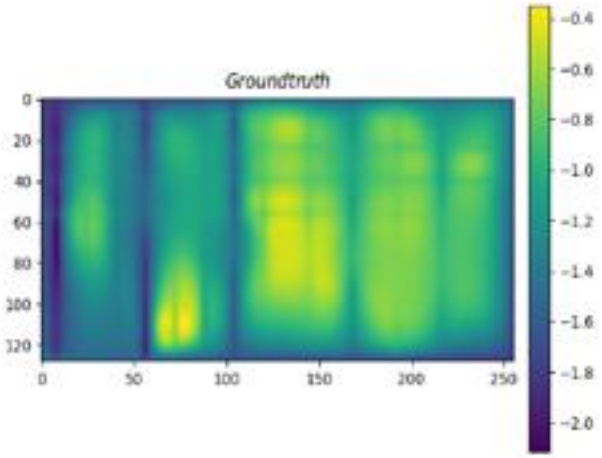
3b. Resultaten techniekontwikkeling

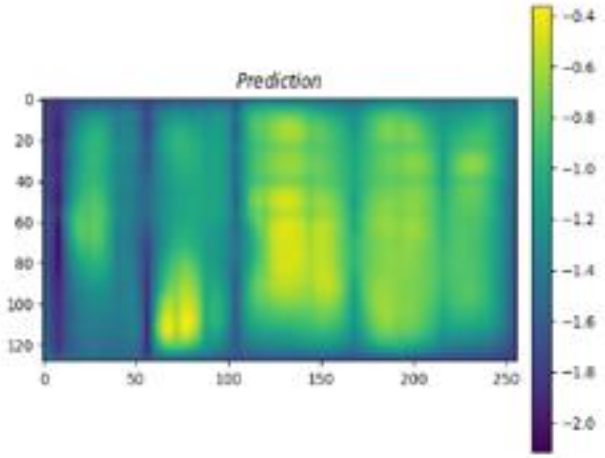
- Updated results presentation and discussion
  - Cases already explored and presented
  - New Cases
- Comparison between various AI techniques

Two cases (previous meeting)

Transmissivity grid to steady-state grid

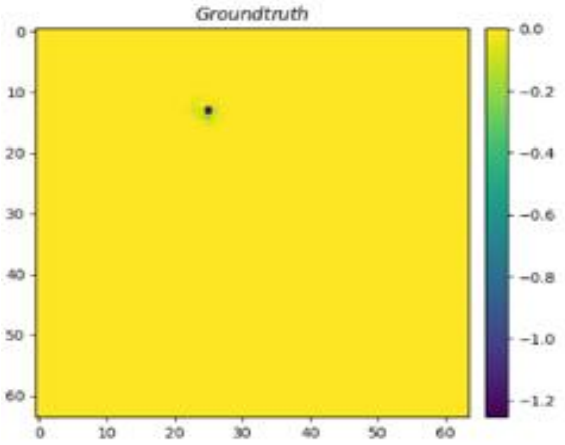
Hypo 01

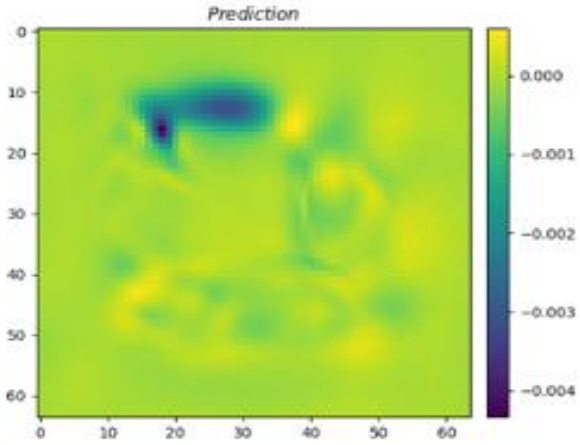




Moving Q to drawdown or steady-state head

Moving well case 1

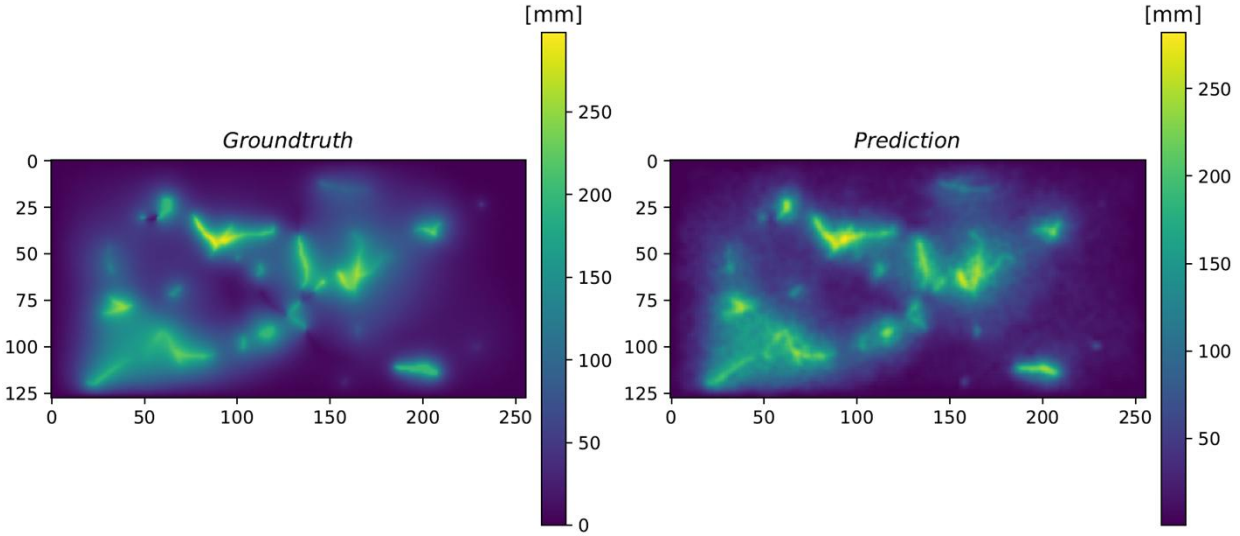




Two new cases

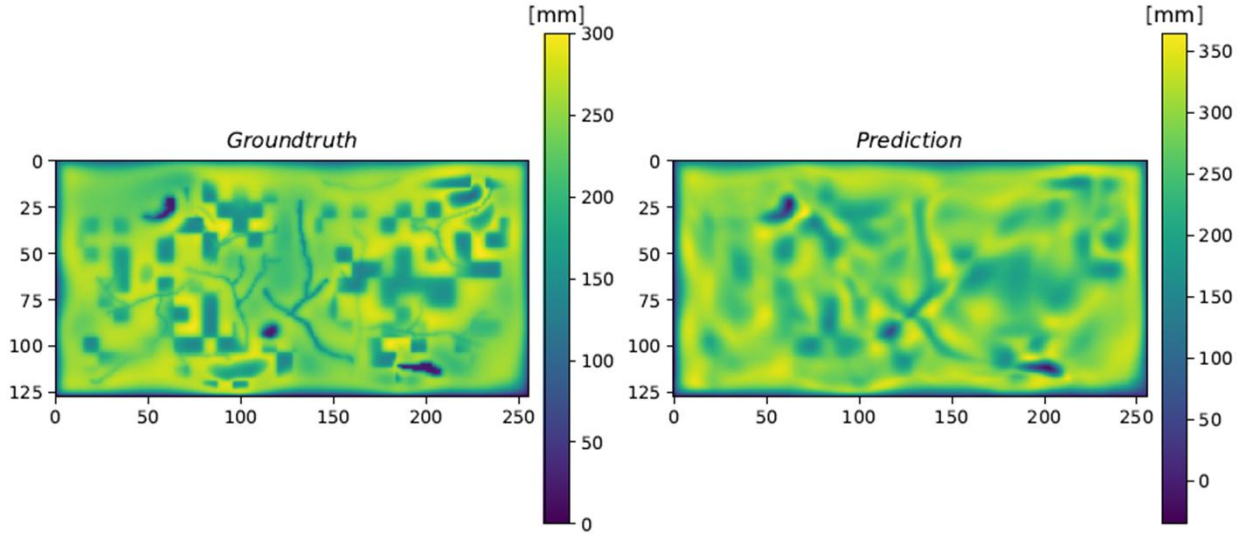
River stage changes to GXG head changes (constant river network)

Hypo 06



Prec + Etp time-series to transient head changes

Hypo 03



Deltares

Techniques VS Runs

	Hypo 01	Hypo 03	Hypo 04	Hypo 06	Moving well 1	Moving well 2
Unet	+	+		+	+	+
GAN	+				+	
DeepOnet	+	+	+	+	+	+
FNO	+			+	+	

Metrics (added in post-processing)

- Mean Absolute Error (MAE)
- Root Mean Squared Error (RMSE)
- Confusion matrix:
  - **True Positives (TPs)**: model predicts pixel head change < -5cm, groundtruth agrees
  - **True Negatives (TNs)**: model predicts pixel head change > -5cm, groundtruth agrees
  - **False Positives (FPs)**: model predicts pixel head change < -5cm, groundtruth disagrees
  - **False Negatives (FNs)**: model predicts pixel head change > -5cm, groundtruth disagrees

		Actual	
		Positive	Negative
Predicted	Positive	True Positive	False Positive
	Negative	False Negative	True Negative

Case Studies

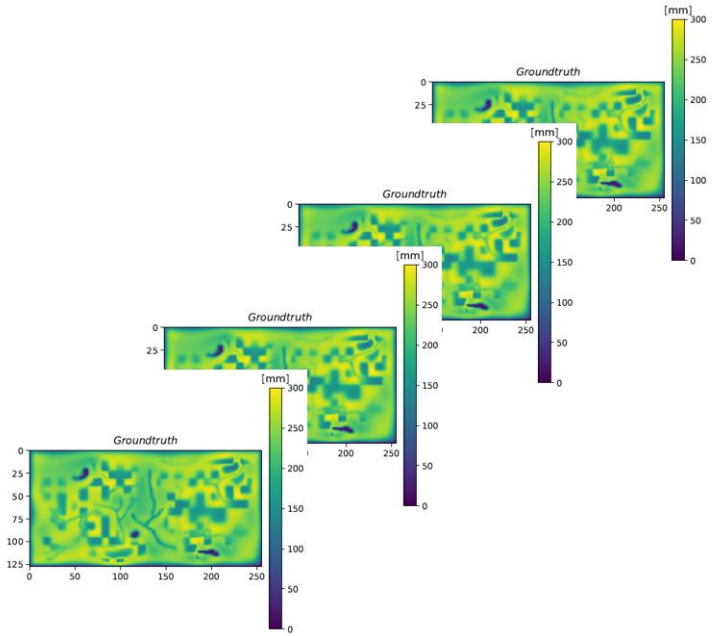
River stages to GXG head – **Hypothetical case 6**

Hypothetical case 6 (GXG)

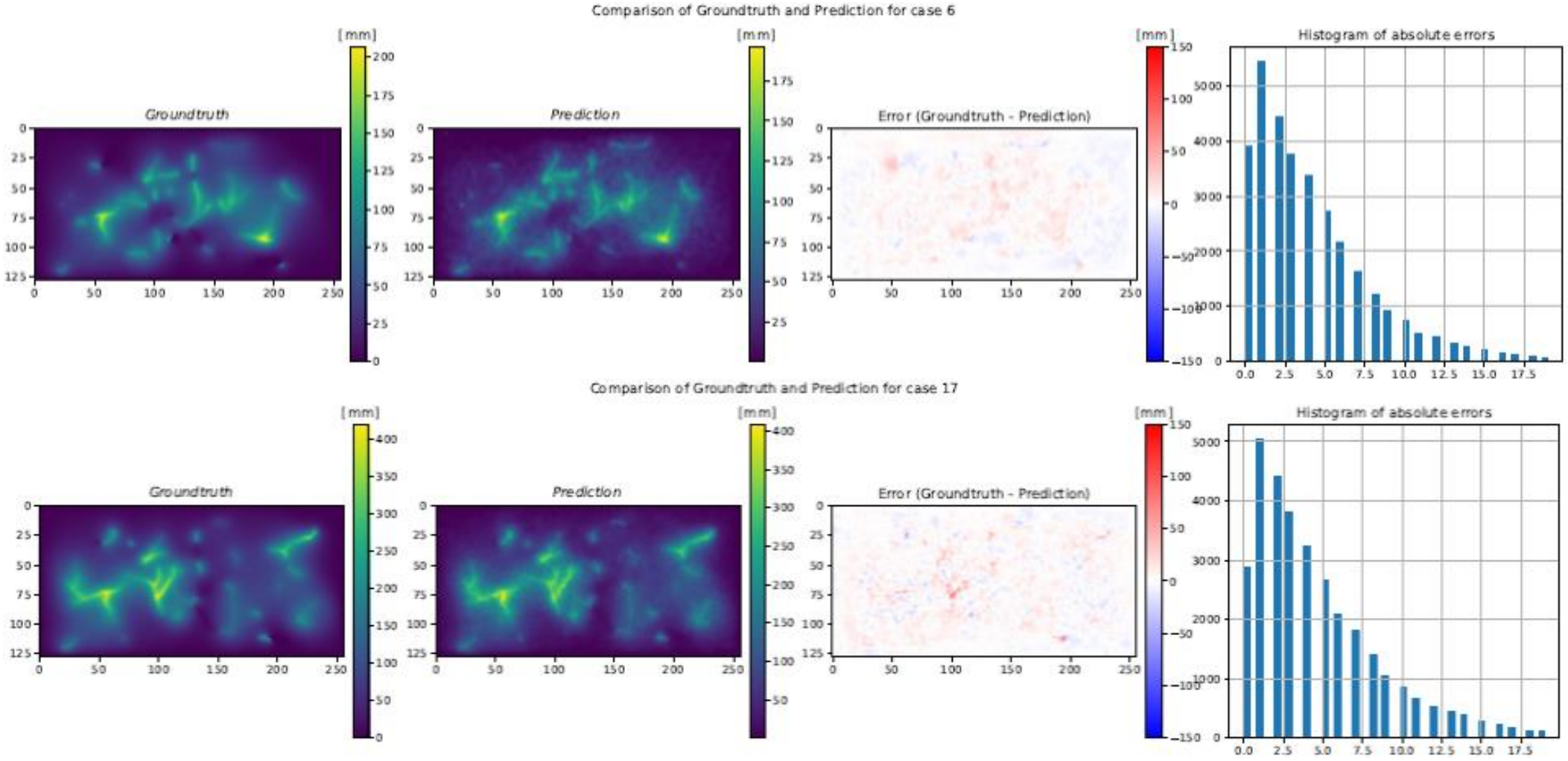
Input:
- Constant river network (pixels) amongst the grid
- Input on river pixels:
  - Absolute river stage
  - River stage changes
- 128 x 256

Model:
- GXG
- LHM
- 128 x 256

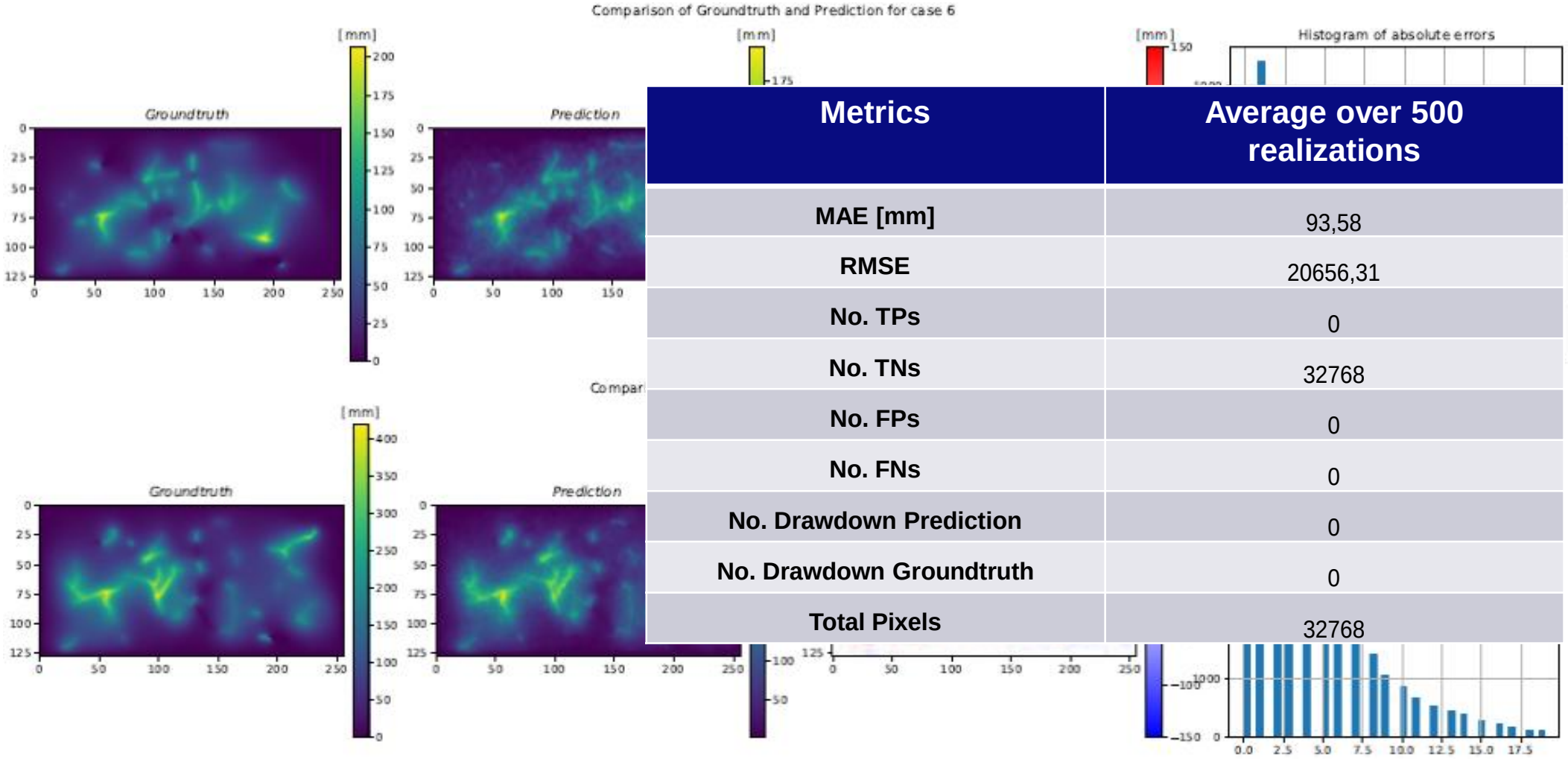
Output:
- GXG grid:
  - Absolute head
  - Head changes
- 2D raster



Unet GLG visualizations

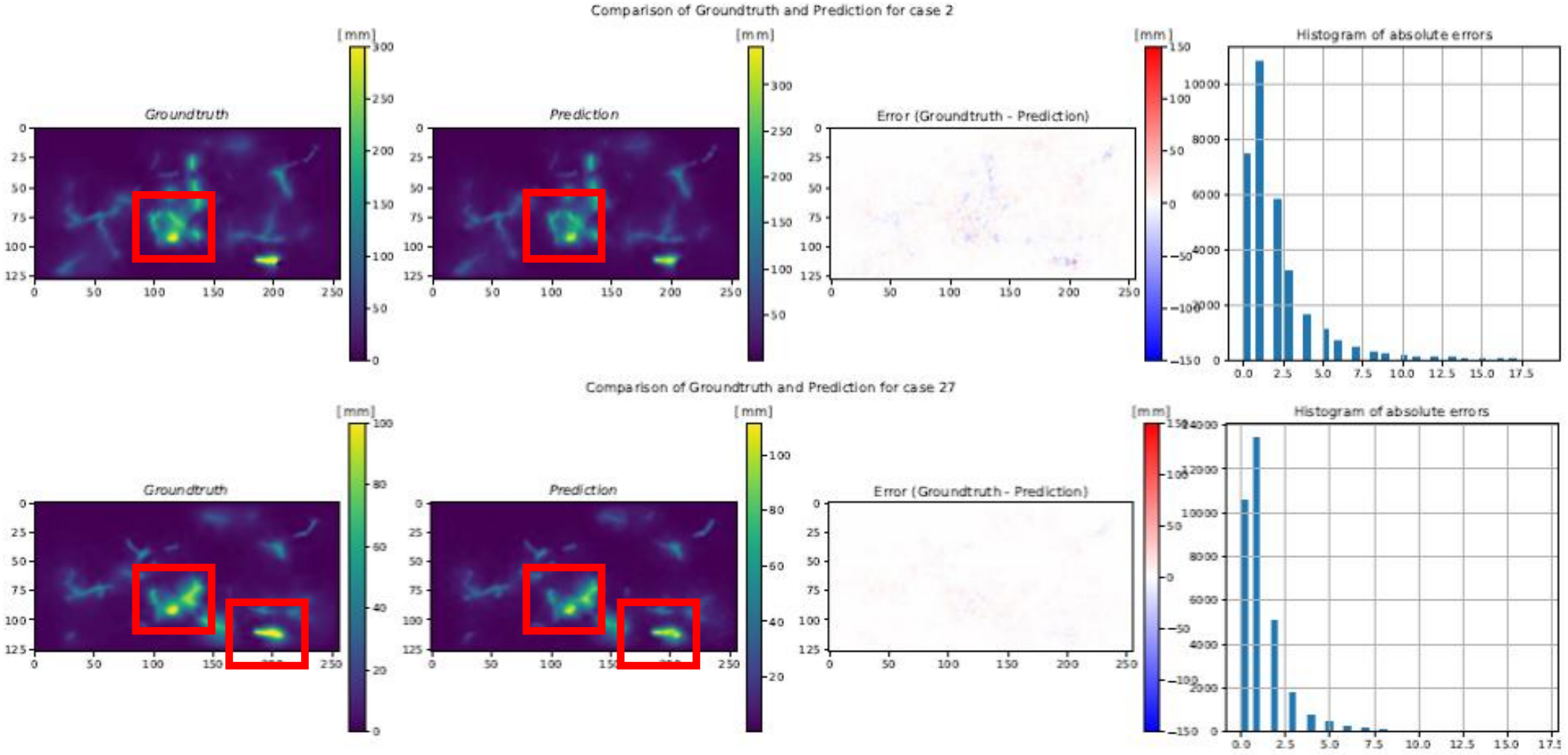


Unet GLG visualizations



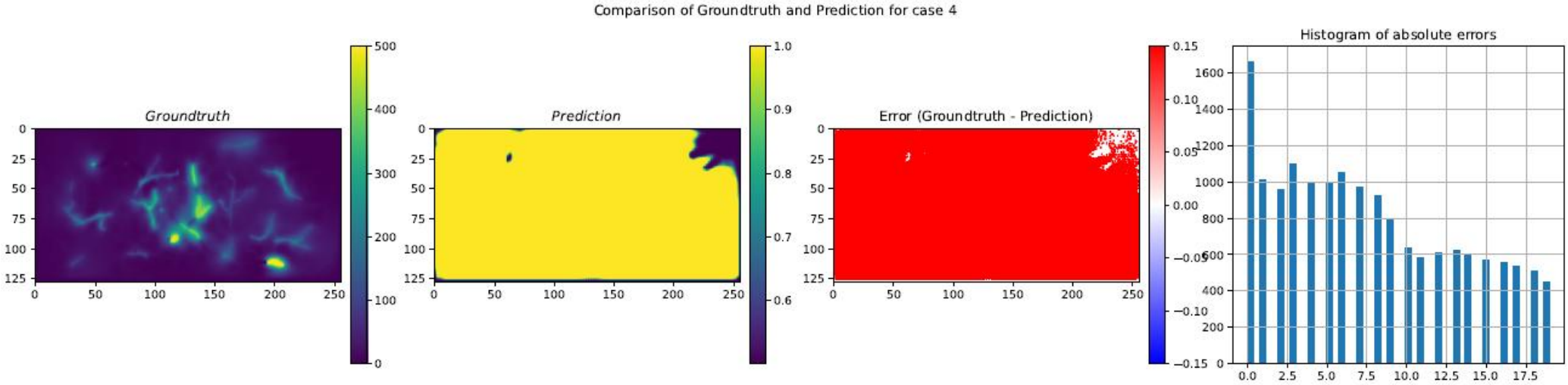
Metrics	Average over 500 realizations
MAE [mm]	93,58
RMSE	20656,31
No. TPs	0
No. TNs	32768
No. FPs	0
No. FNs	0
No. Drawdown Prediction	0
No. Drawdown Groundtruth	0
Total Pixels	32768

Unet GHG visualizations

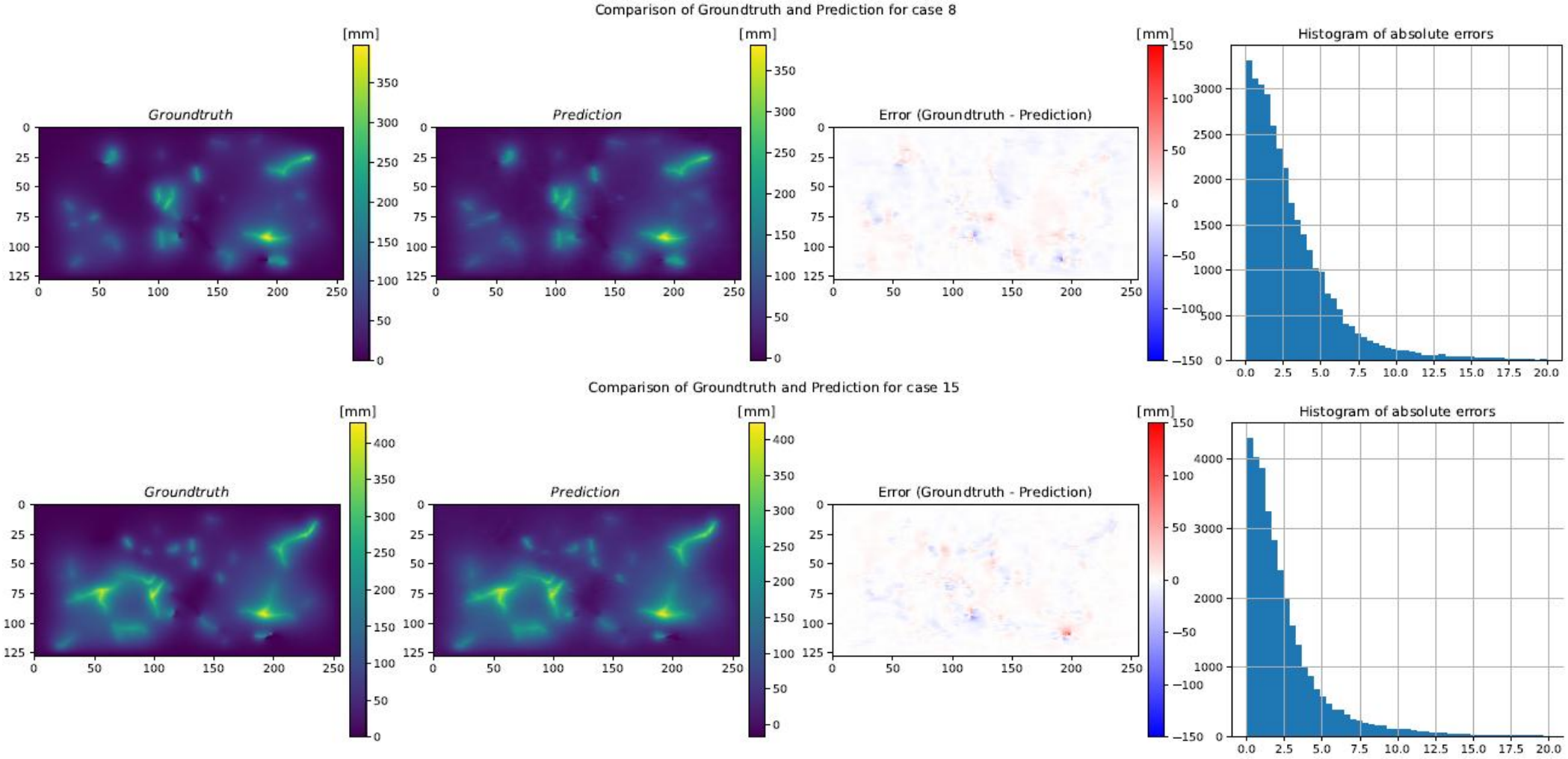


Deltares

Adding attention

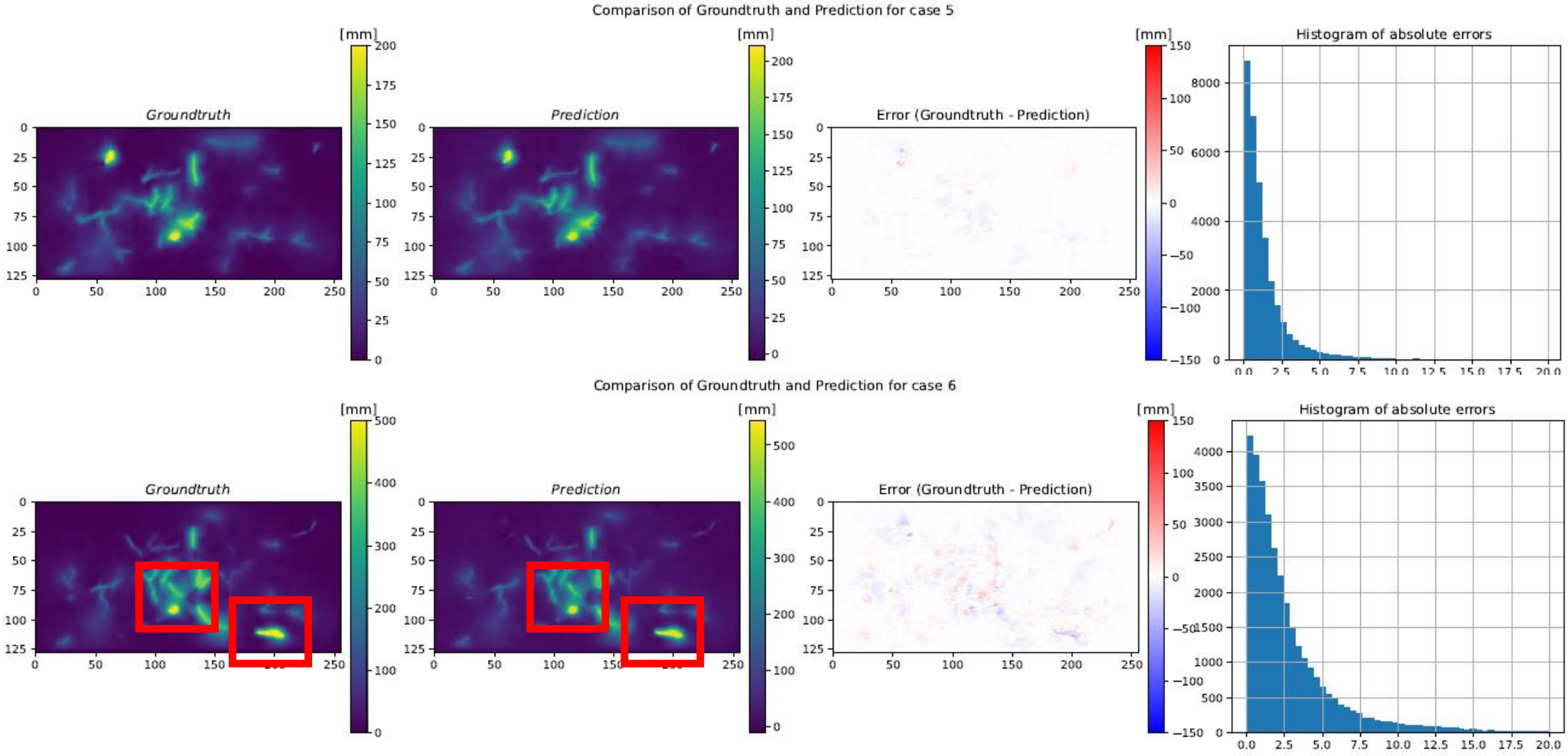


FNO GLG visualizations



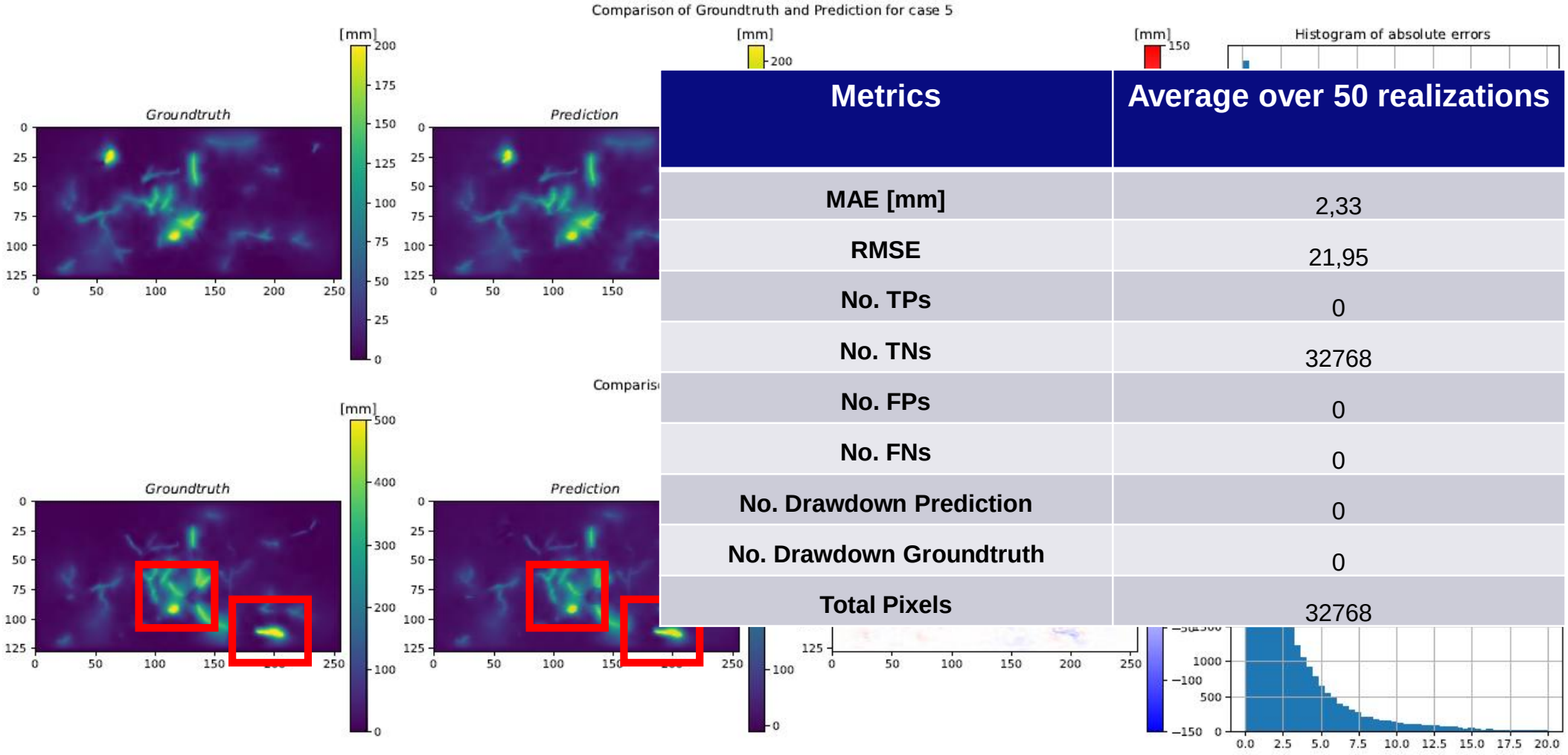
Deltares

FNO GHG visualizations



Deltares

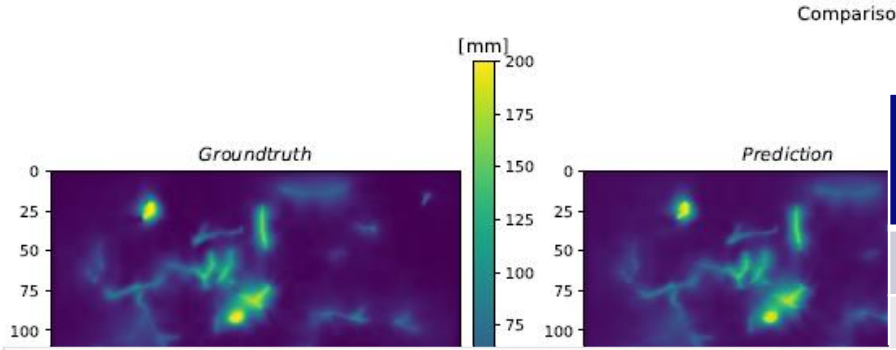
FNO GHG visualizations

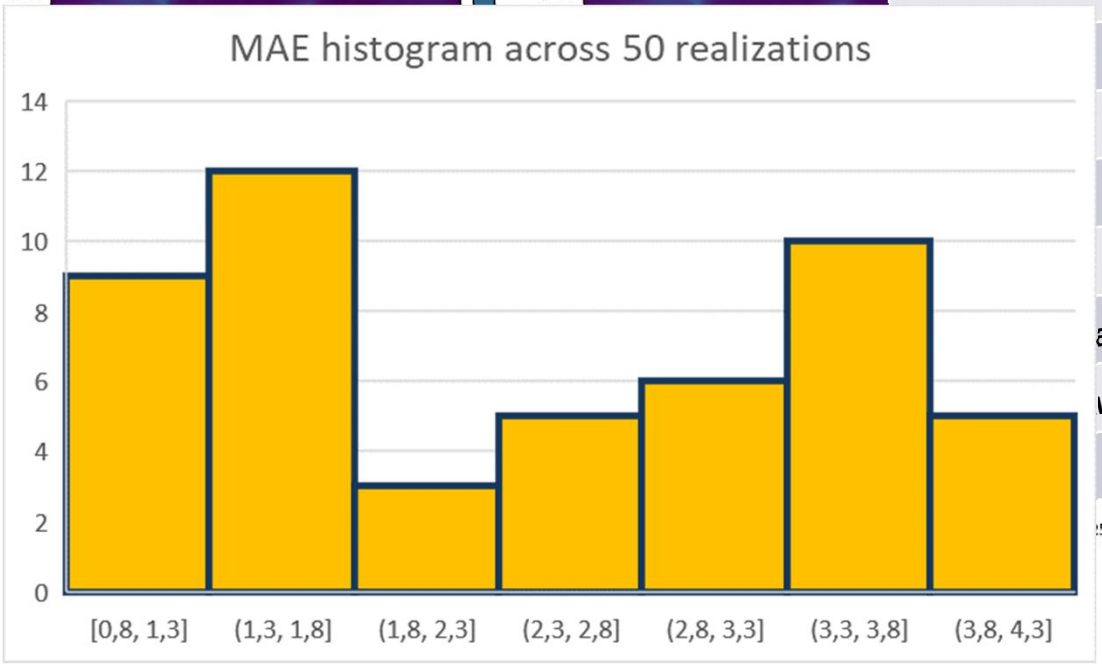


Metrics	Average over 50 realizations
MAE [mm]	2,33
RMSE	21,95
No. TPs	0
No. TNs	32768
No. FPs	0
No. FNs	0
No. Drawdown Prediction	0
No. Drawdown Groundtruth	0
Total Pixels	32768

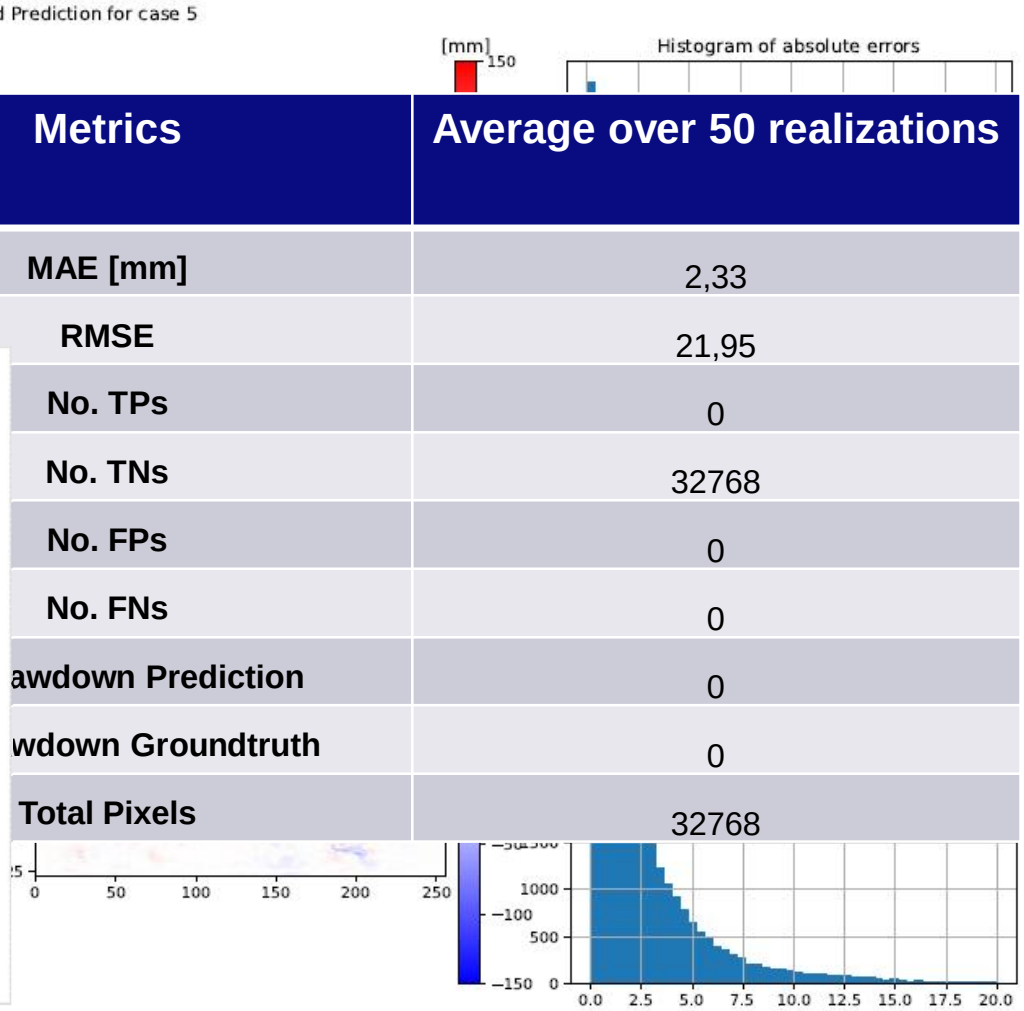
Deltares

FNO GHG visualizations



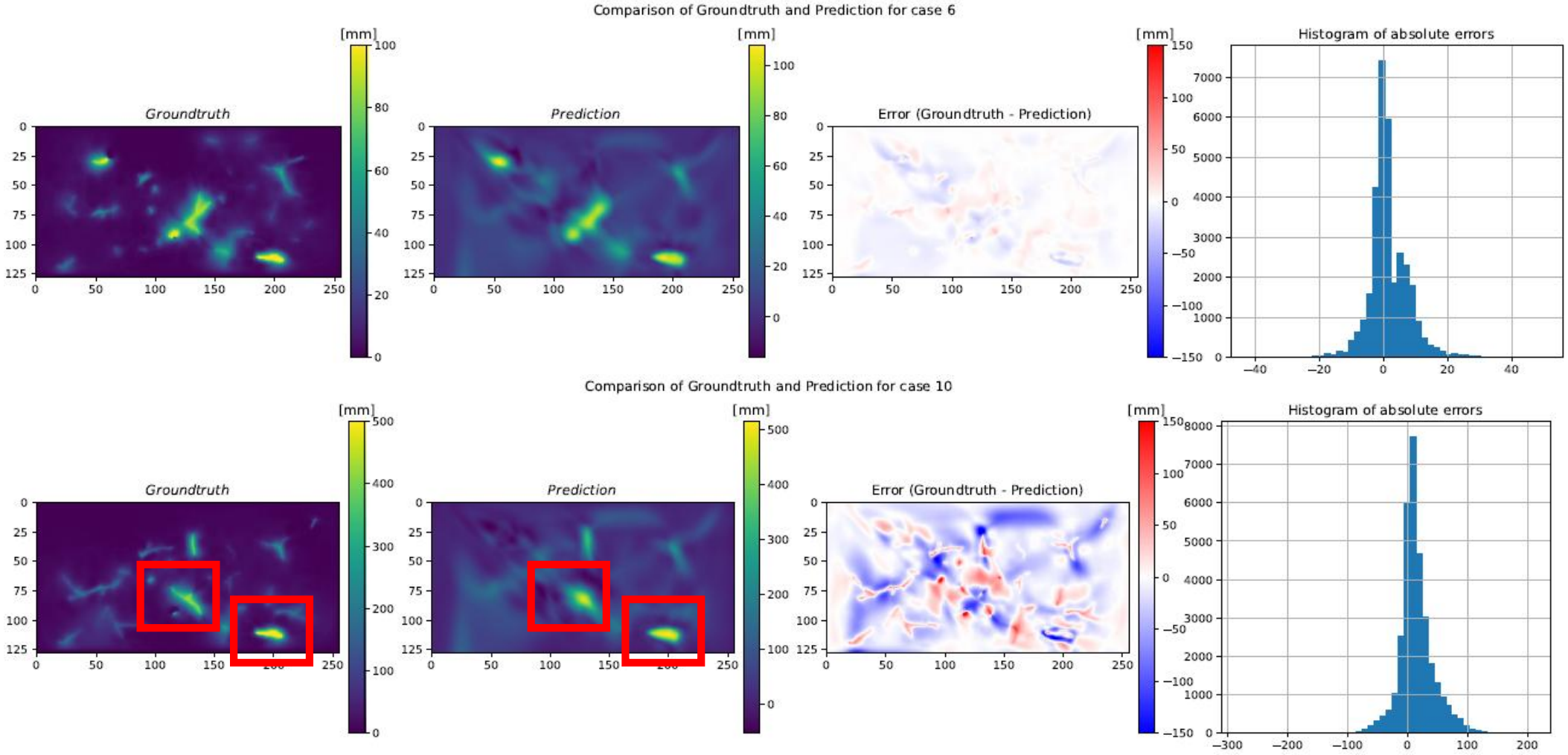


Metrics	Average over 50 realizations
MAE [mm]	2,33
RMSE	21,95
No. TPs	0
No. TNs	32768
No. FPs	0
No. FNs	0
awdown Prediction	0
wdown Groundtruth	0
Total Pixels	32768



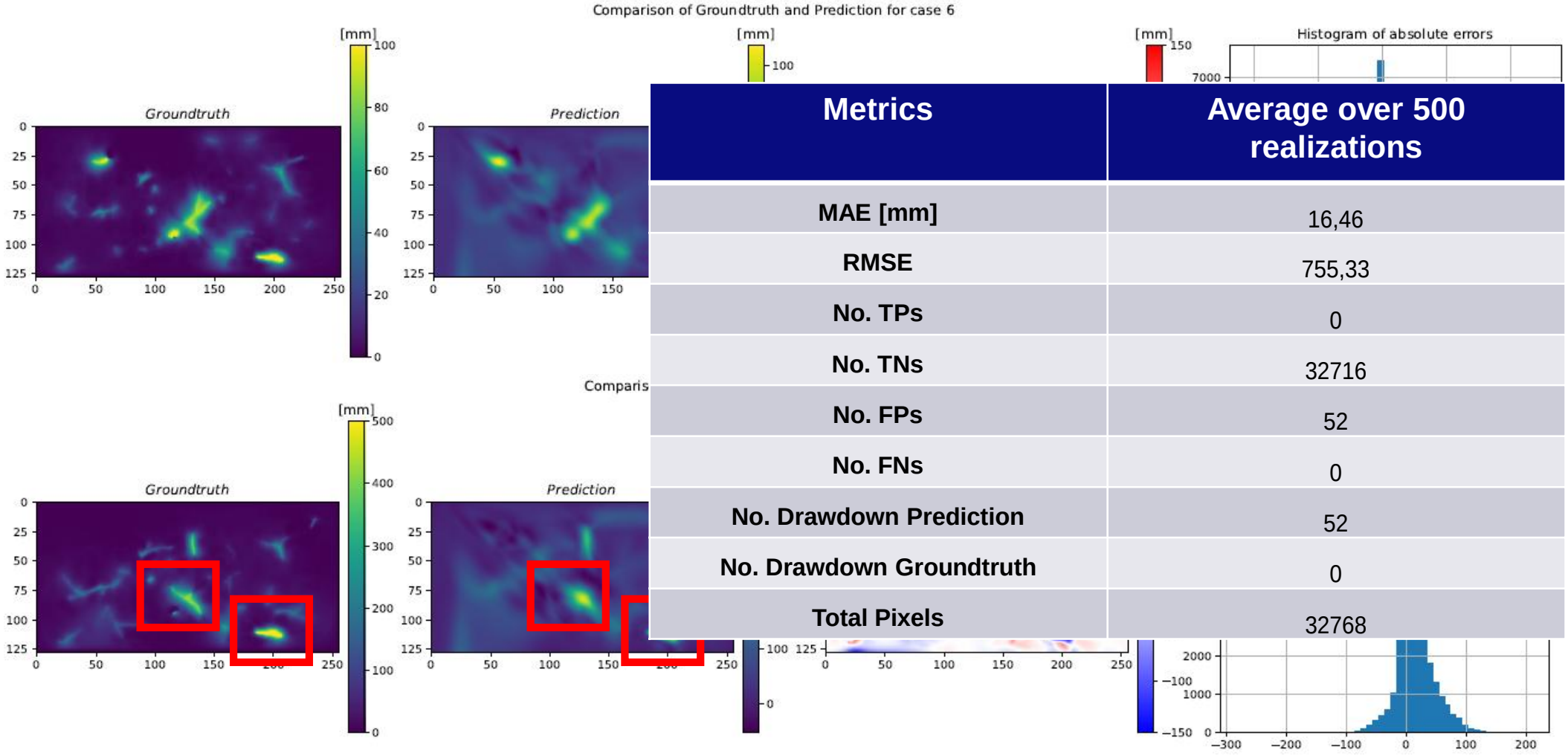
Deltares

DON GHG visualizations



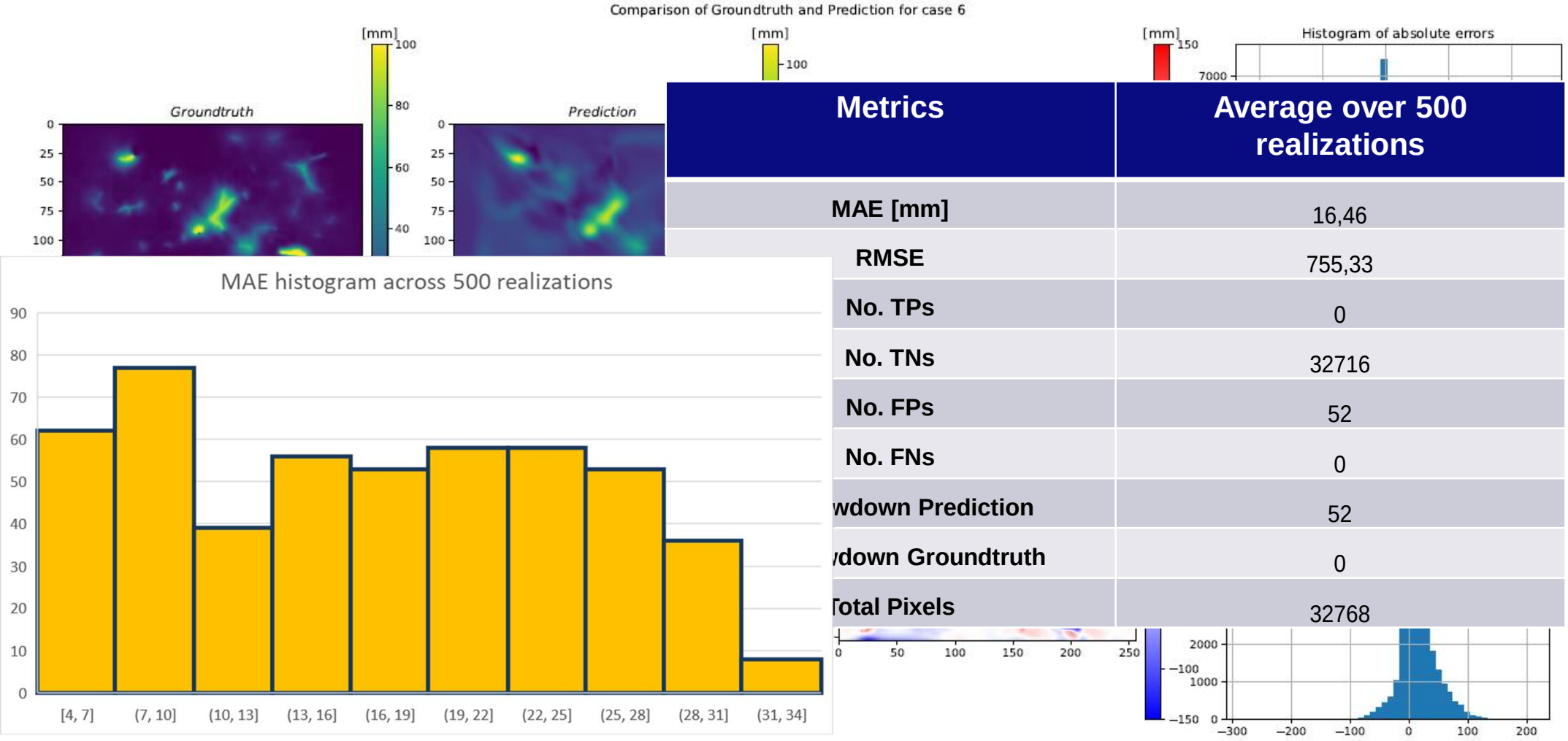
Deltares

DON GHG visualizations



Metrics	Average over 500 realizations
MAE [mm]	16,46
RMSE	755,33
No. TPs	0
No. TNs	32716
No. FPs	52
No. FNs	0
No. Drawdown Prediction	52
No. Drawdown Groundtruth	0
Total Pixels	32768

DON GHG visualizations



Metrics	Average over 500 realizations
MAE [mm]	16,46
RMSE	755,33
No. TPs	0
No. TNs	32716
No. FPs	52
No. FNs	0
wdown Prediction	52
down Groundtruth	0
Total Pixels	32768

Deltares

Case Studies

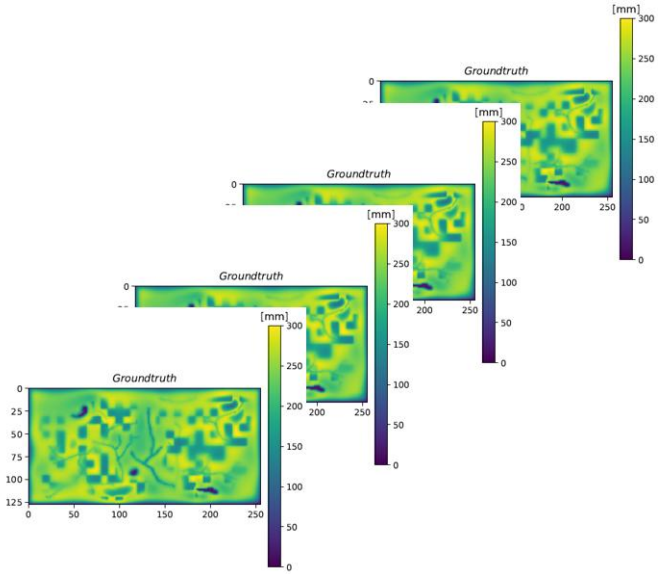
Time-series to transient head – **Hypothetical case 3**

Hypothetical case 3 (transient)

Input:
- Precipitation and potential evapotranspiration time-series
- Daily resolution
- Starting from April 1st until the date of prediction
- Maximum length 185 days

Model:
- GXG
- LHM
- 128 x 256

Output:
- Transient head:
  - Absolute head
  - Head changes
- 2D raster
- Predicting 7 different dates from mid-April to October



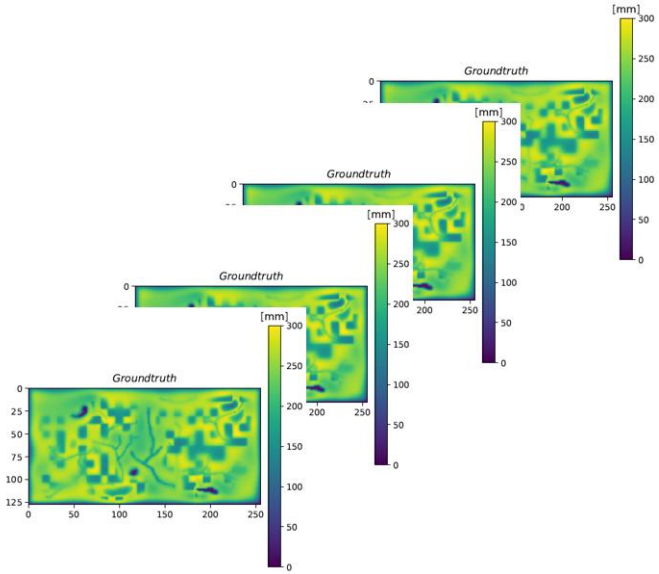
Deltares

Hypothetical case 3 (transient)

Input:
- Precipitation and potential evapotranspiration time-series
- Daily resolution
- Starting from April 1st until the date of prediction
- Maximum length 185 days

Model:
- GXG
- LHM
- 128 x 256

Output:
- Transient head:
  - Absolute head
  - Head changes
- 2D raster
- Predicting 7 different dates from mid-April to October



Output 3 different dates:
- 14-04-2010 with 14 days input
- 01-07-2010 with 92 days input
- 01-10-2010 with 184 days input

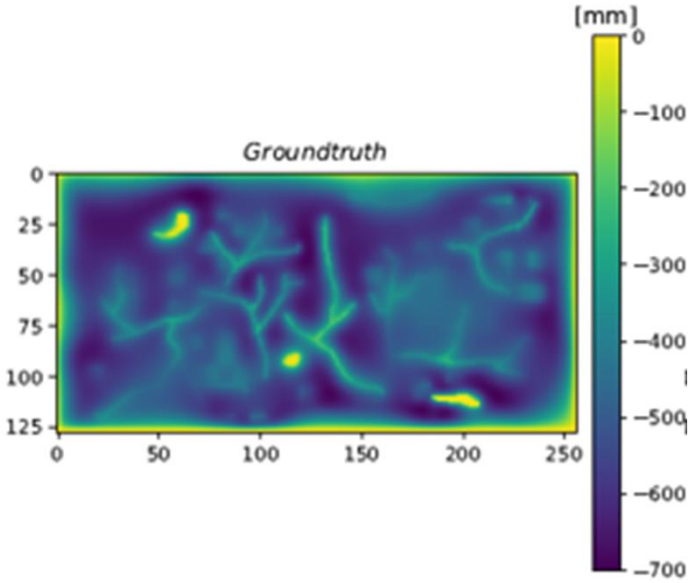
Prediction for Date No.1

Precipitation

ETp

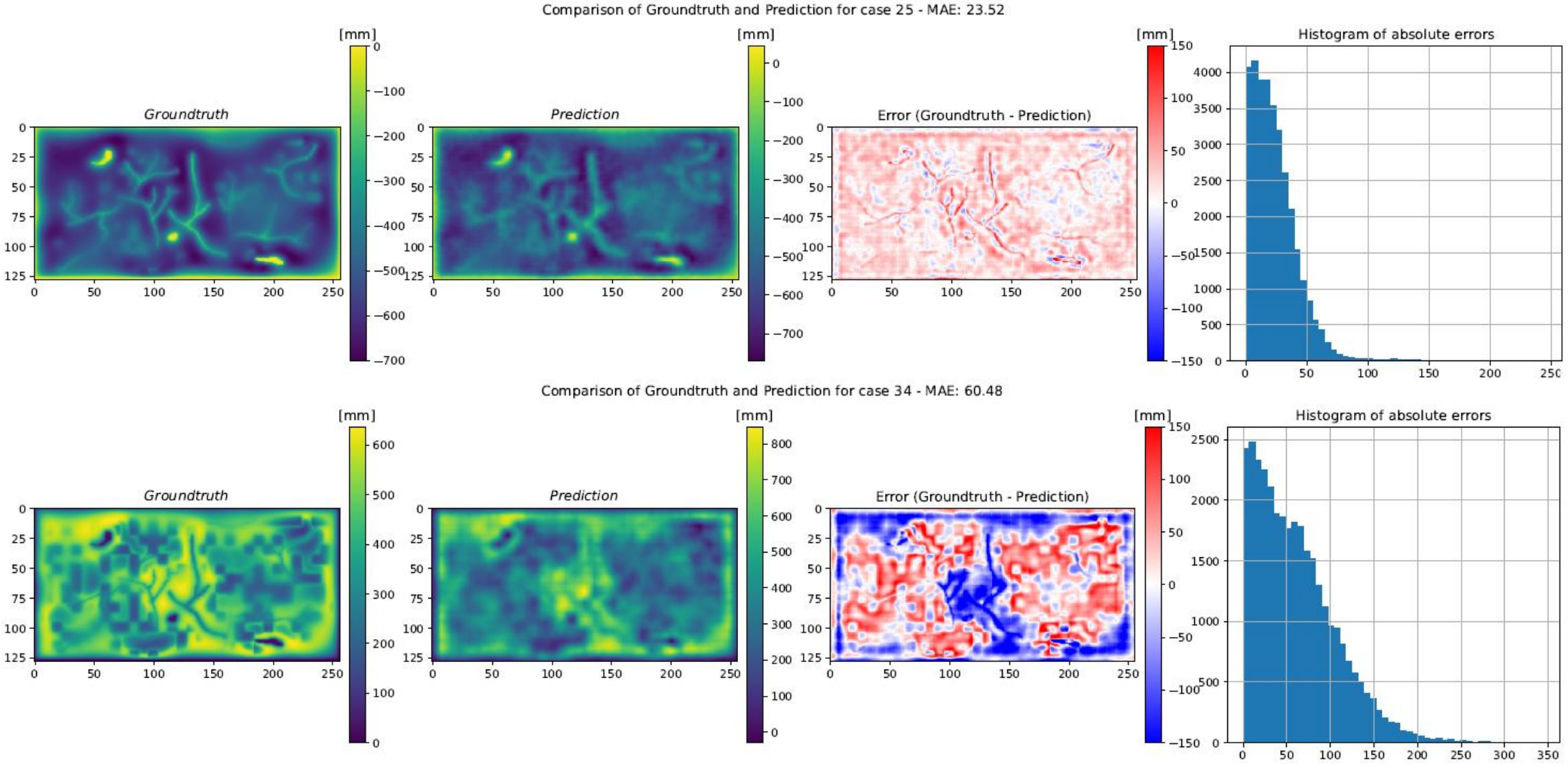
14 days

14-04-2010



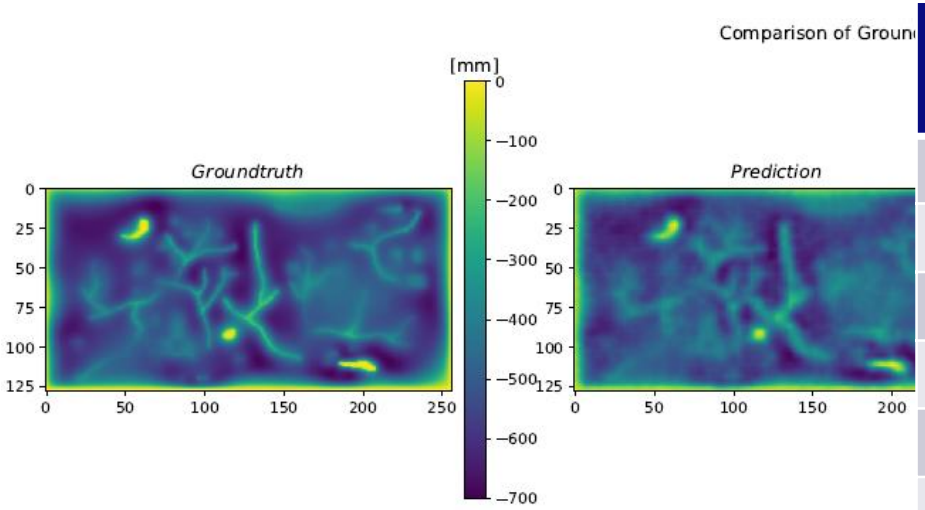
Deltares

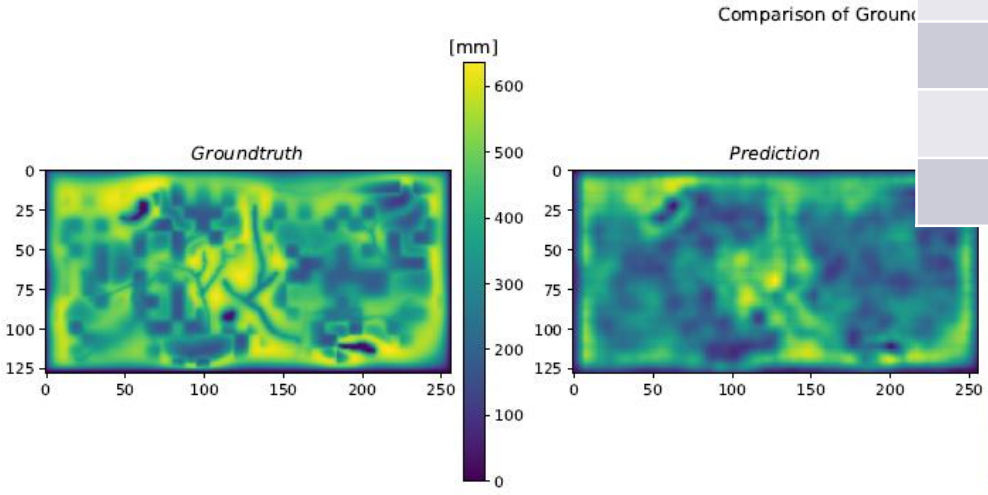
Encoder-Decoder Date No.1 visualizations



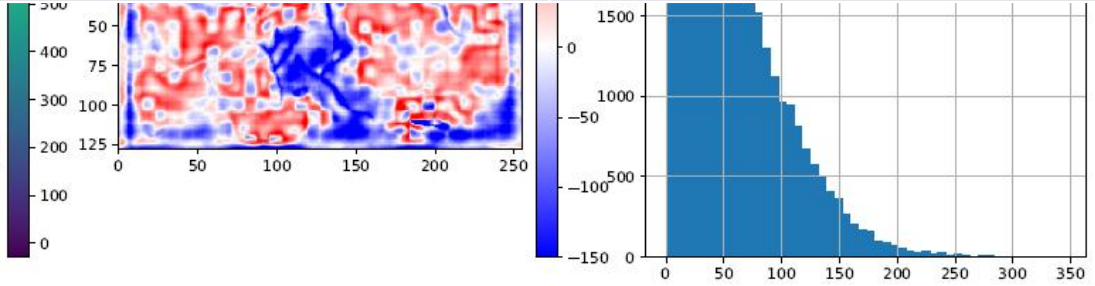
Deltares

Encoder-Decoder Date No.1 visualizations



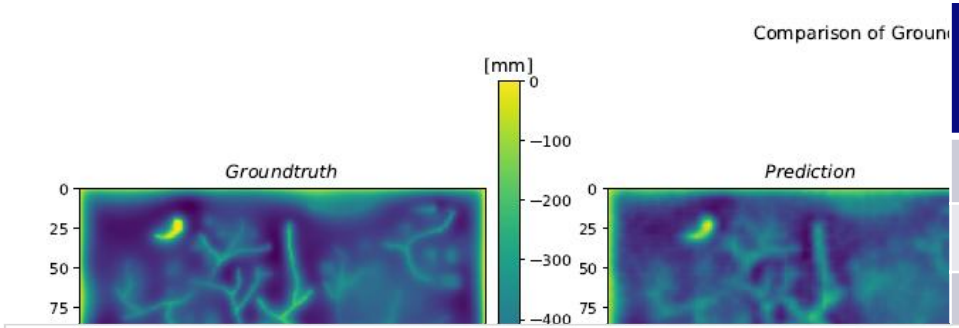


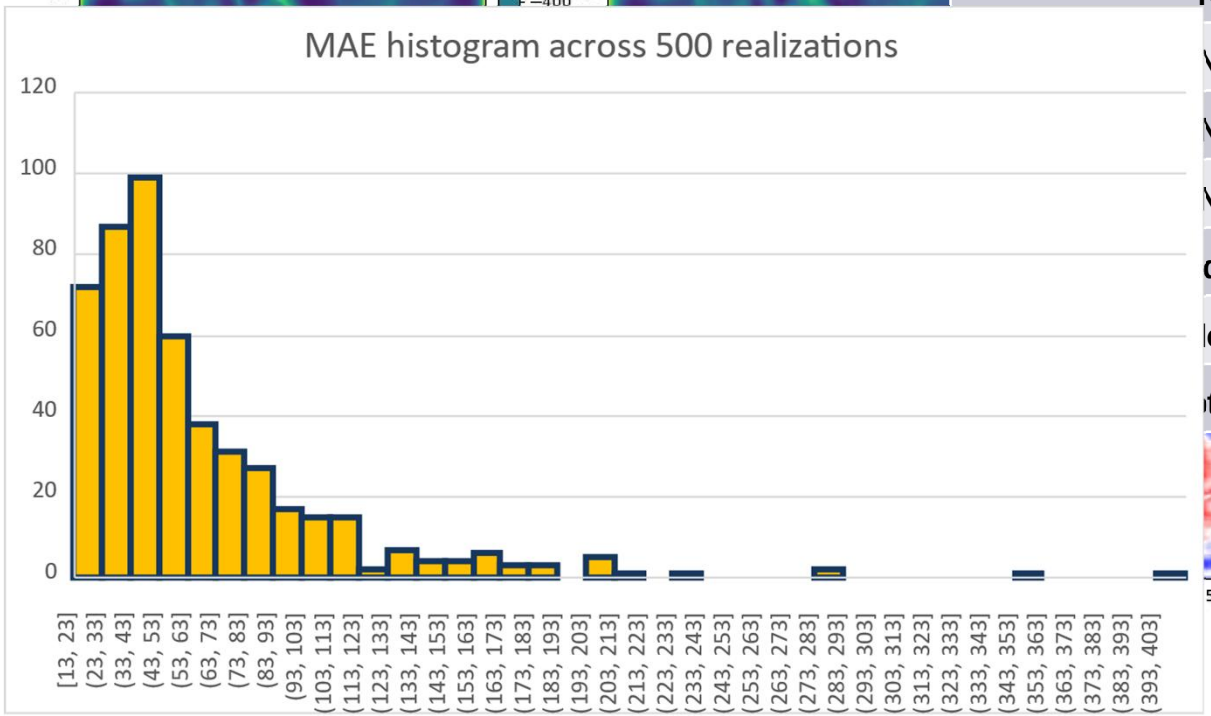
Metrics	Average over 500 realizations
MAE [mm]	56,93
RMSE	6838,99
No. TPs	15602,62
No. TNs	15346,69
No. FPs	818,52
No. FNs	1000,17
No. Drawdown Prediction	16421,14
No. Drawdown Groundtruth	16602,79
Total Pixels	32768



Deltares

Encoder-Decoder Date No.1 visualizations





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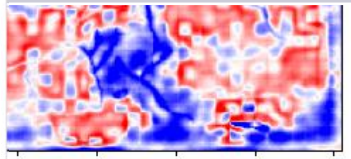
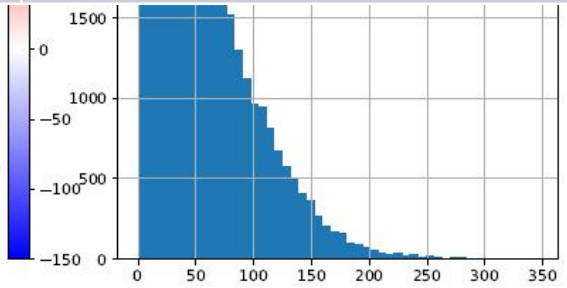
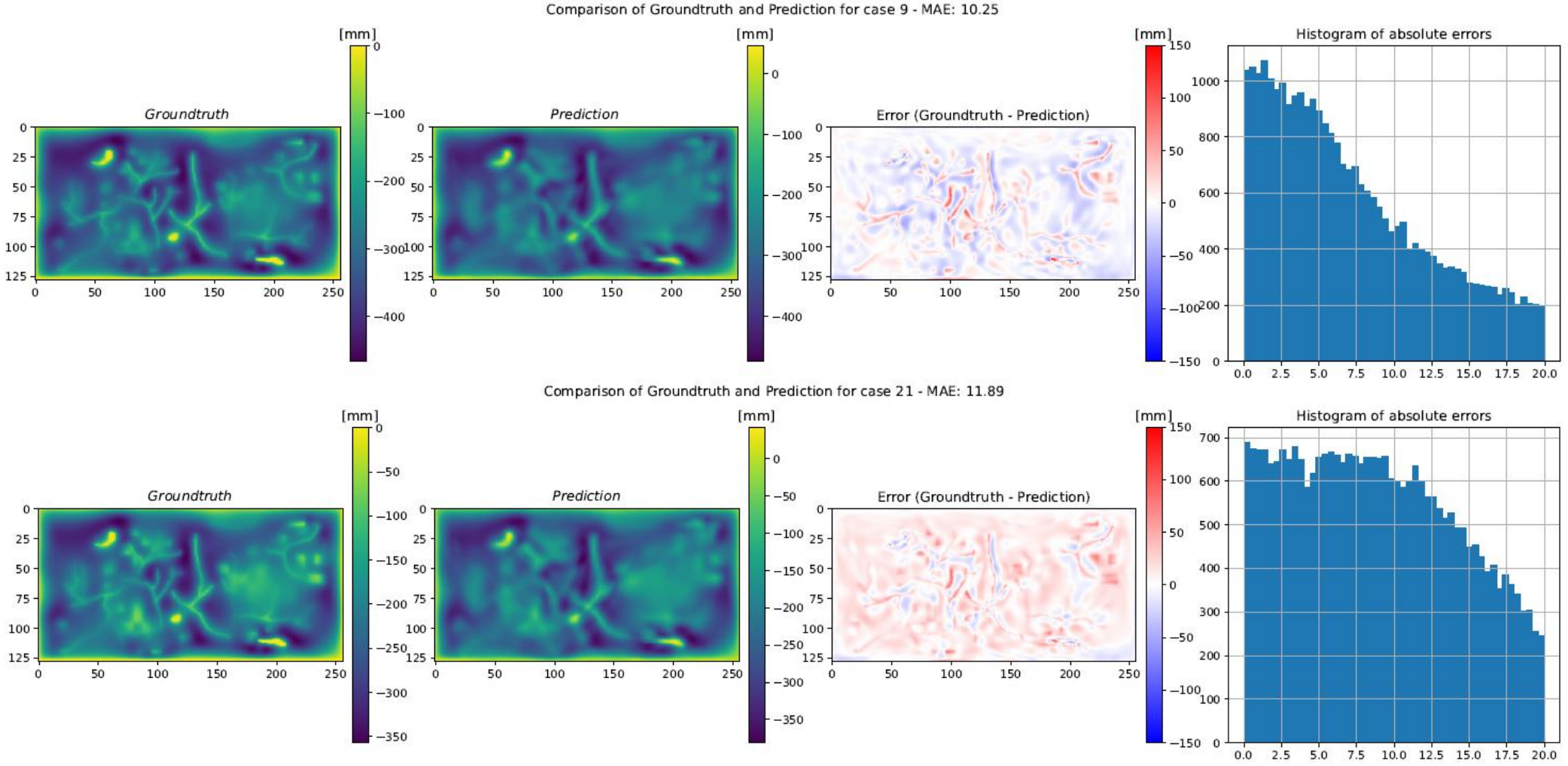
own Groundtruth	16602,79
tal Pixels	32768





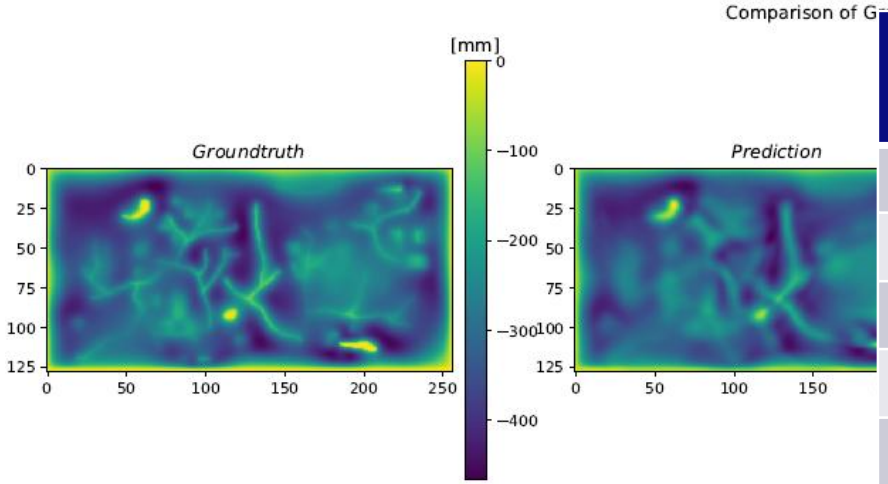
Deltares

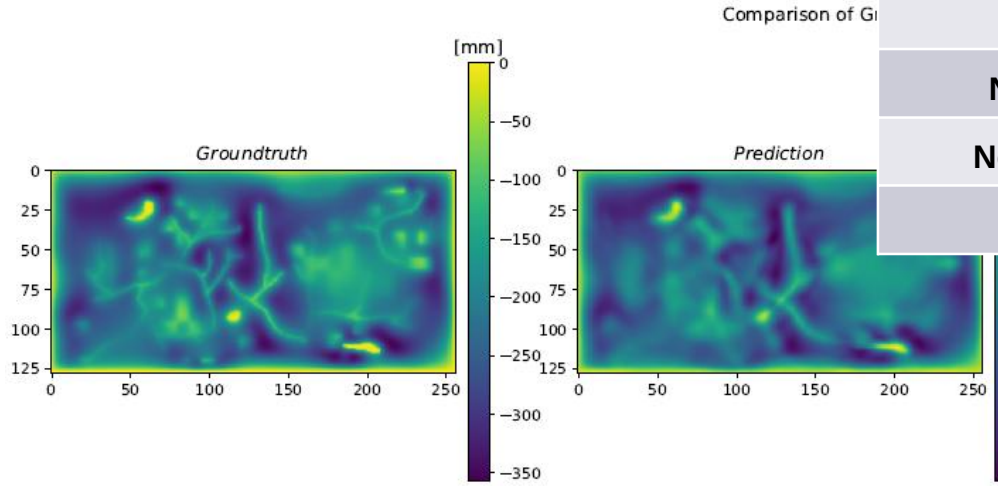
Default DON Date No.1 visualizations



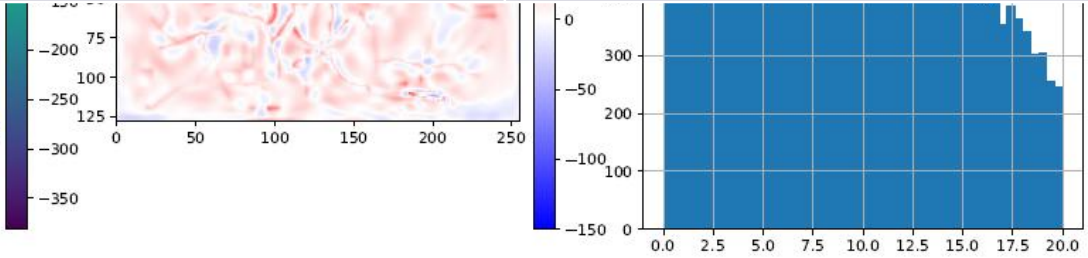
Deltares

Default DON Date No.1 visualizations

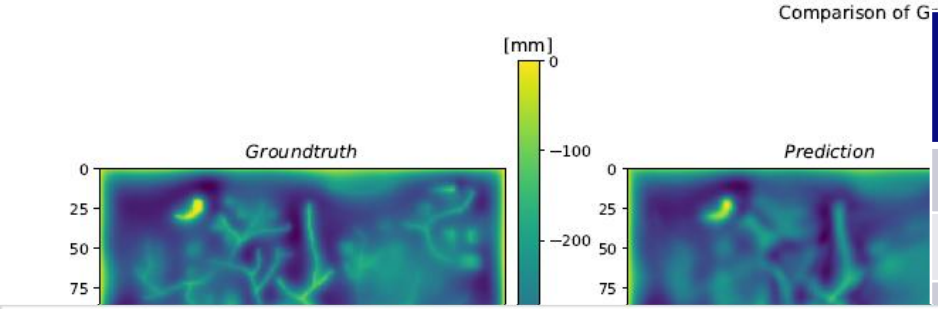




Metrics	Average over 500 realizations
MAE [mm]	61,62
RMSE	8072,08
No. TPs	15815,19
No. TNs	14837,02
No. FPs	1031,73
No. FNs	1084,06
No. Drawdown Prediction	16846,92
No. Drawdown Groundtruth	16899,25
Total Pixels	32768



Default DON Date No.1 visualizations



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MAE [mm]	61,62
RMSE	8072,08
No. TPs	15815,19
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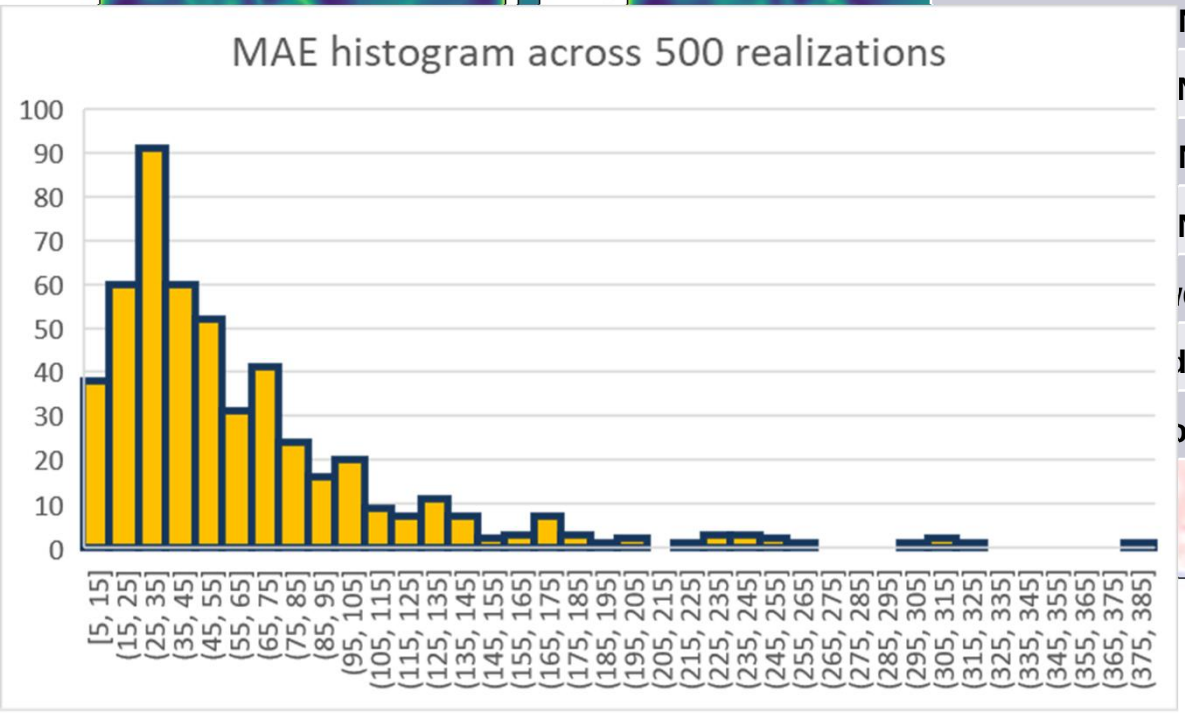
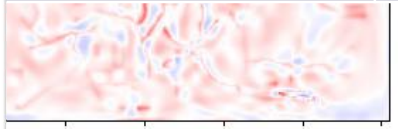
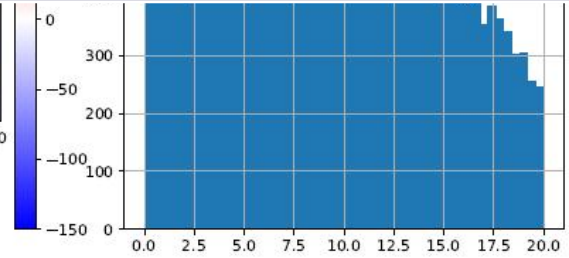
No. FPs	1031,73
No. FNs	1084,06
ydown Prediction	16846,92
down Groundtruth	16899,25
otal Pixels	32768

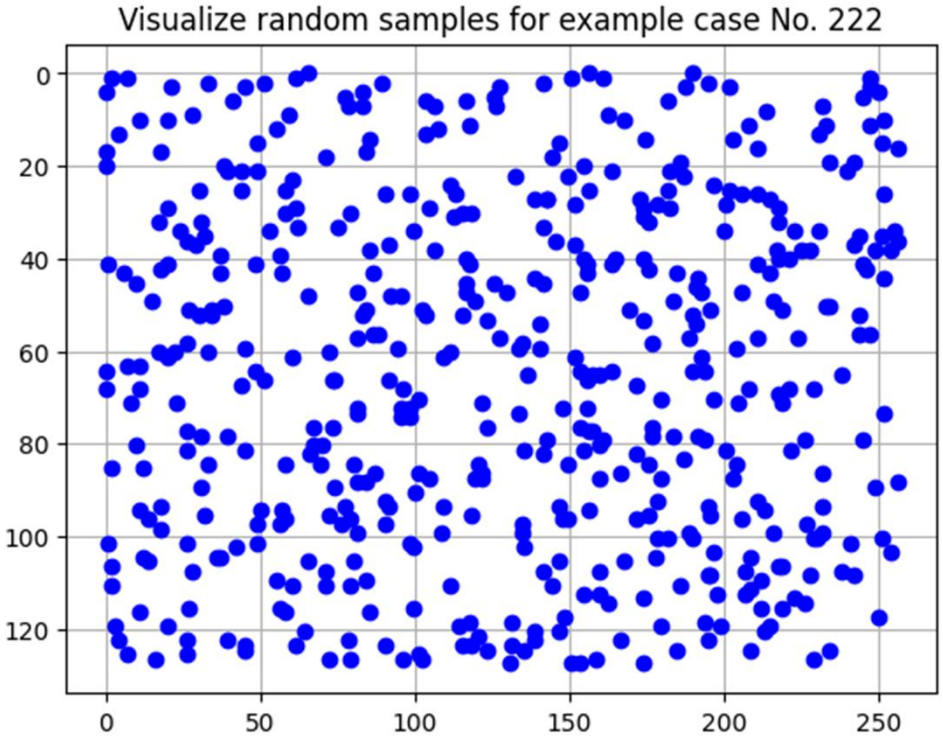


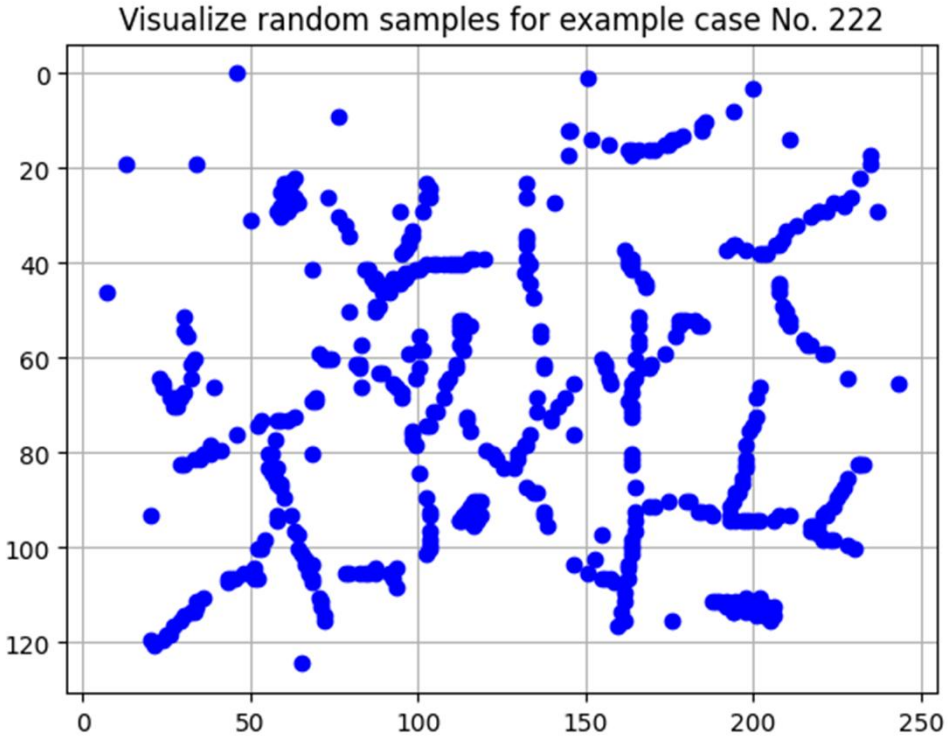




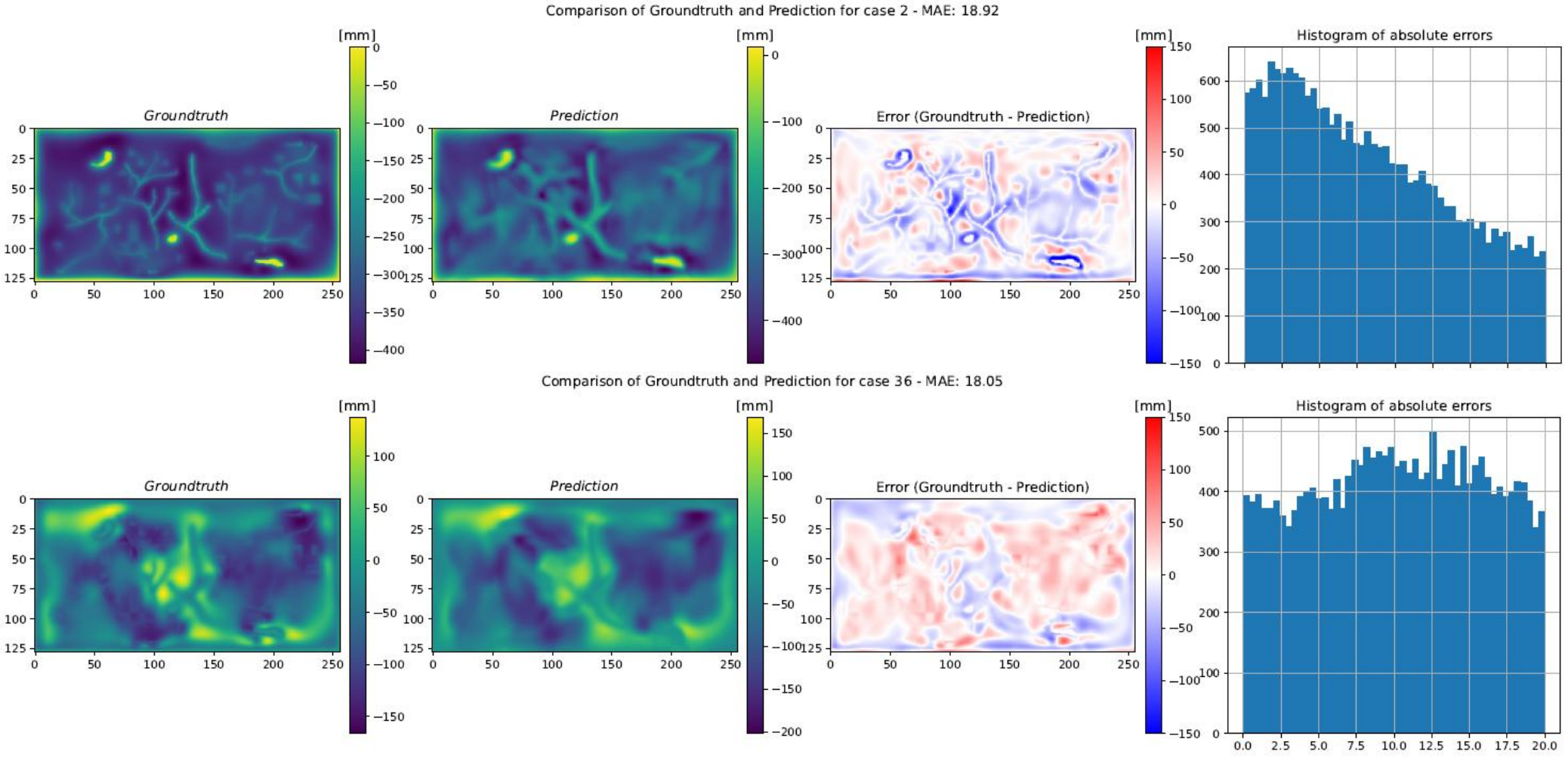
Deltares

DON GHG sampling tecniques



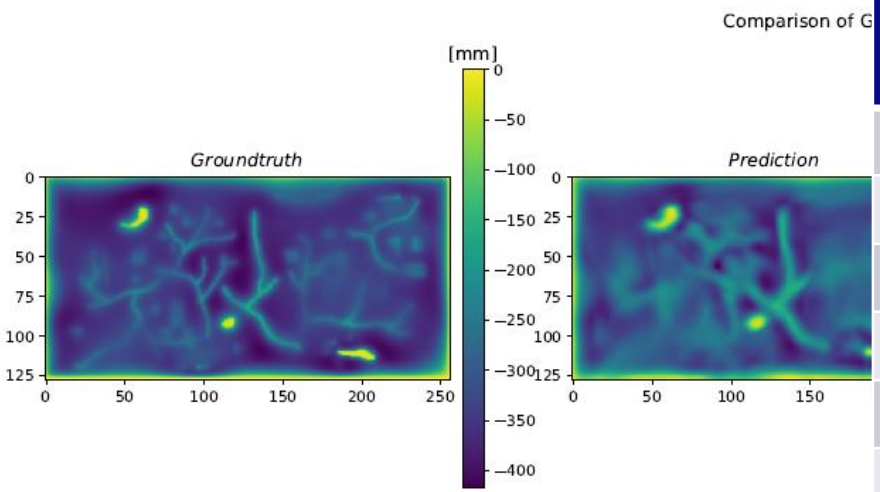


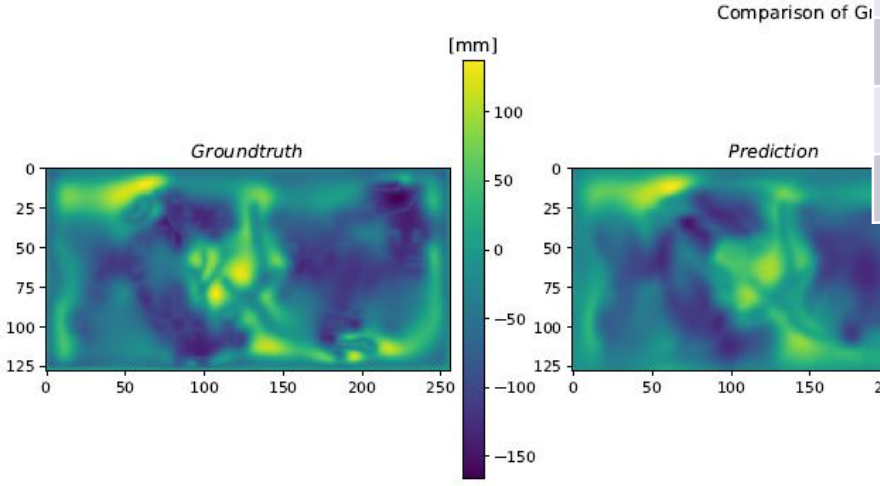
Default DON Date No.1 - sampling river network



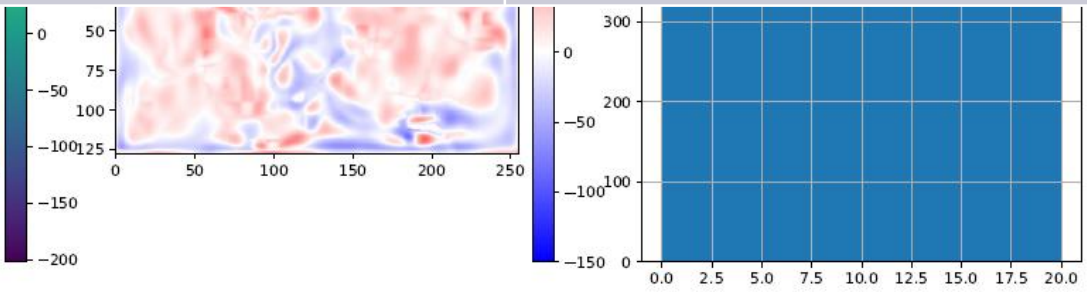
Deltares

Default DON Date No.1 - sampling river network



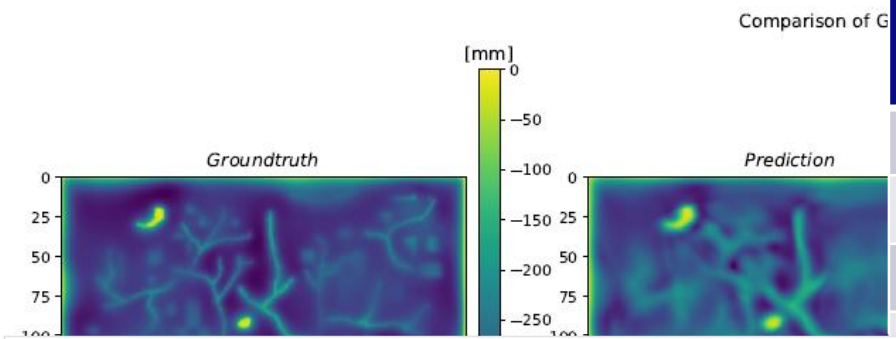


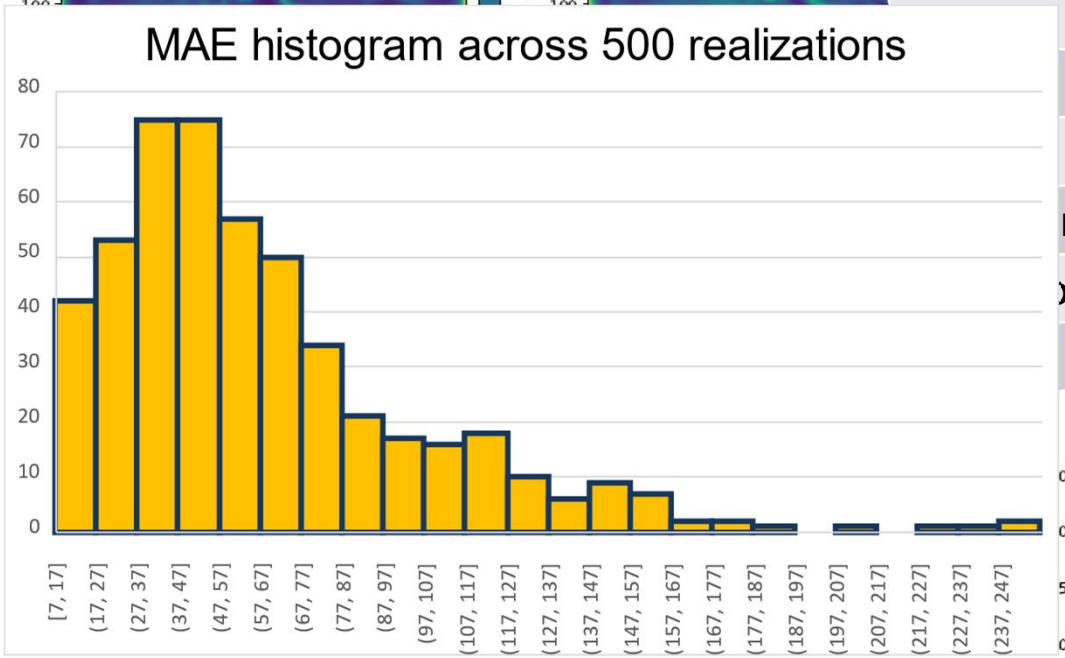
Metrics	Average over 500 realizations
MAE [mm]	57,95
RMSE	6489,41
No. TPs	14953,75
No. TNs	15803,2
No. FPs	791,974
No. FNs	1219,07
No. Drawdown Prediction	15745,73
No. Drawdown Groundtruth	16172,83
Total Pixels	32768



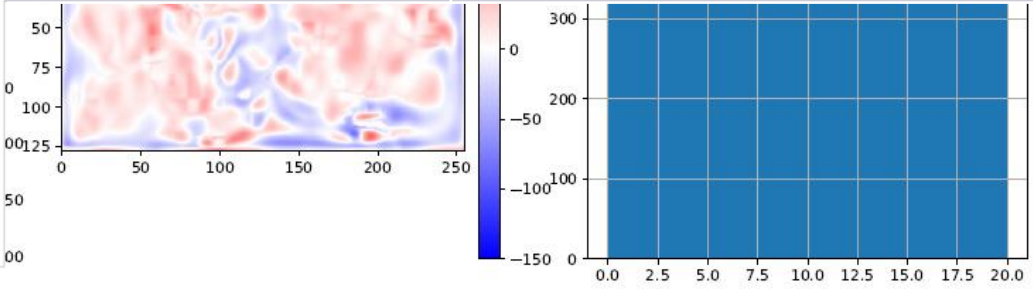
Deltares

Default DON Date No.1 - sampling river network





Metrics	Average over 500 realizations
MAE [mm]	57,95
RMSE	6489,41
No. TPs	14953,75
No. TNs	15803,2
No. FPs	791,974
No. FNs	1219,07
Drawdown Prediction	15745,73
Drawdown Groundtruth	16172,83
Total Pixels	32768



Deltares

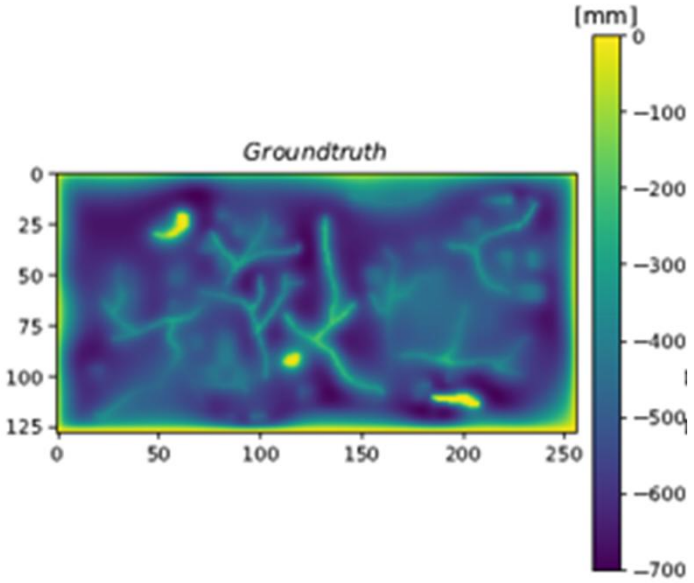
Prediction for Date No.4

Precipitation

ETp

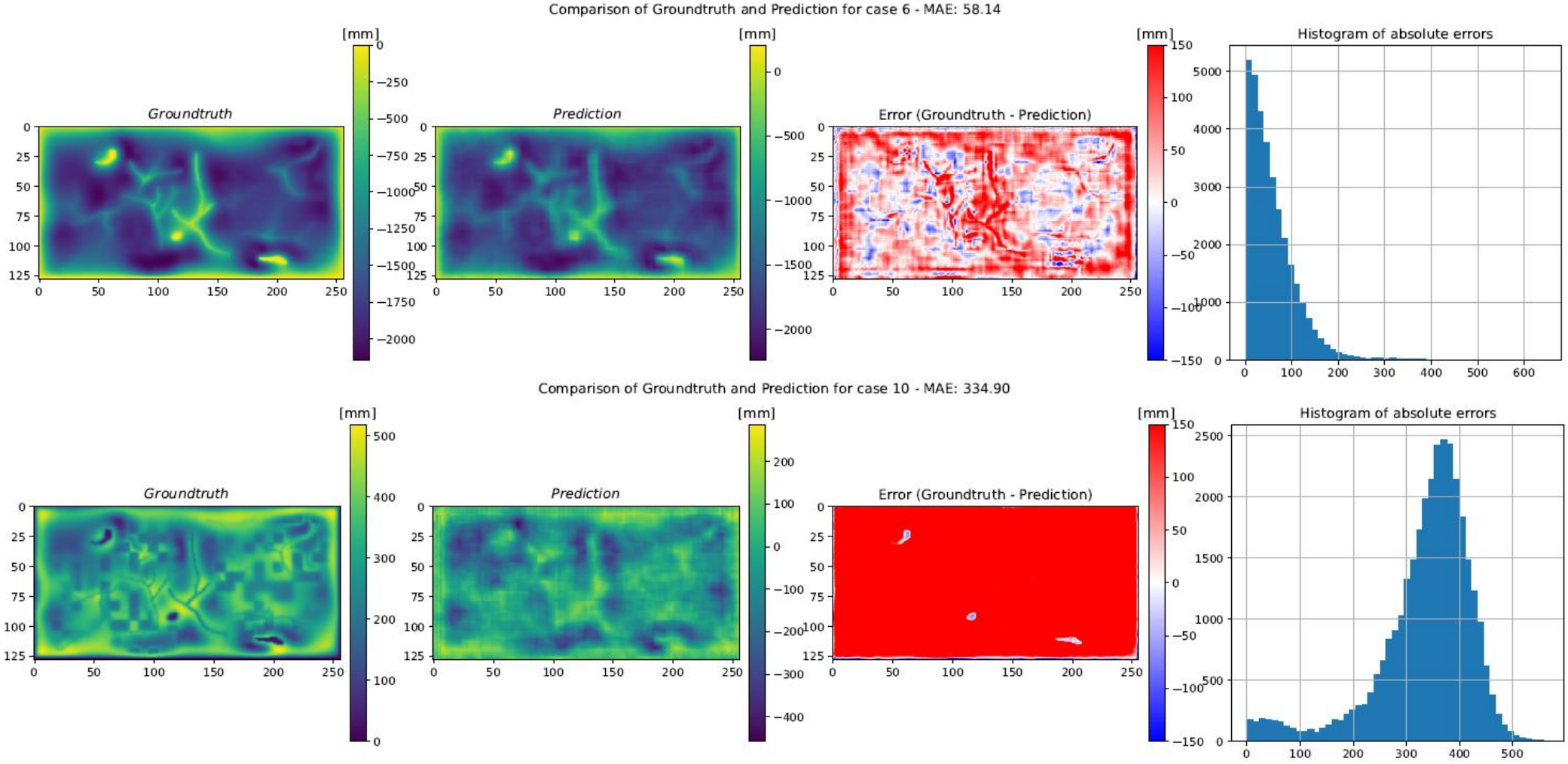
92 days

01-07-2010



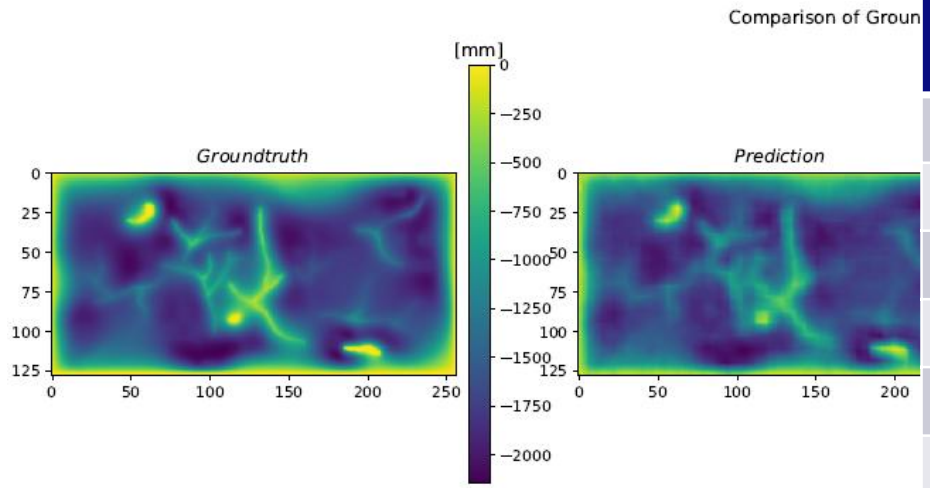
Deltares

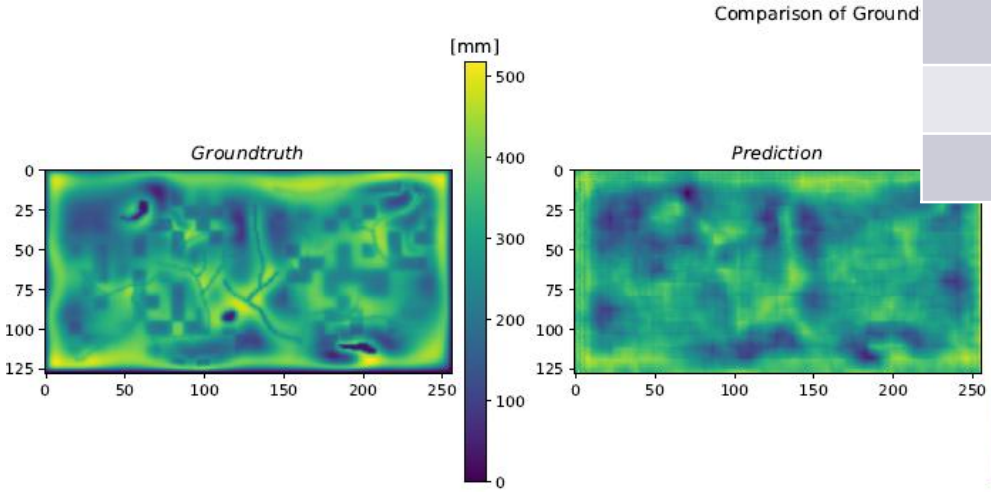
Encoder-Decoder Date No.4 visualizations



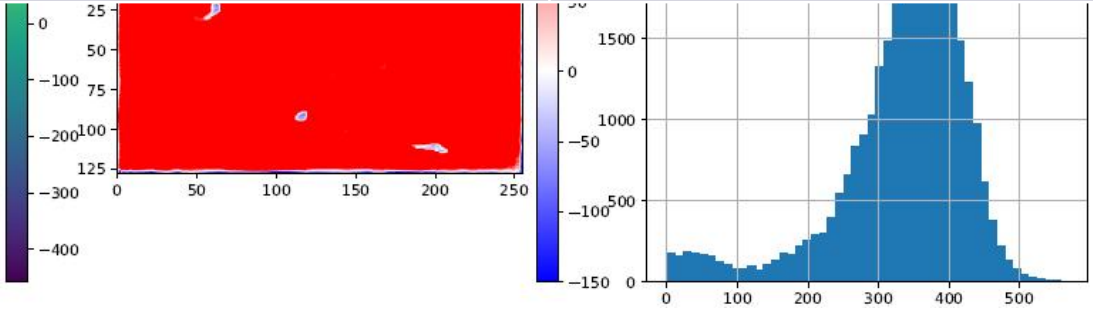
Deltares

Encoder-Decoder Date No.4 visualizations



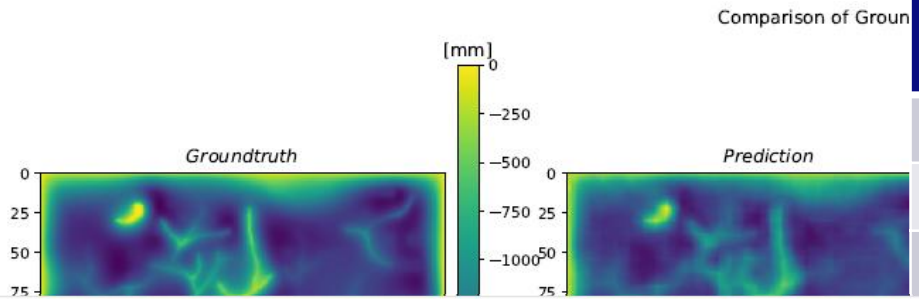


Metrics	Average over 500 realizations
MAE [mm]	100,50
RMSE	19039,67
No. TPs	17527,58
No. TNs	12882,48
No. FPs	1818,18
No. FNs	539,754
No. Drawdown Prediction	19345,76
No. Drawdown Groundtruth	18067,34
Total Pixels	32768



Deltares

Encoder-Decoder Date No.4 visualizations



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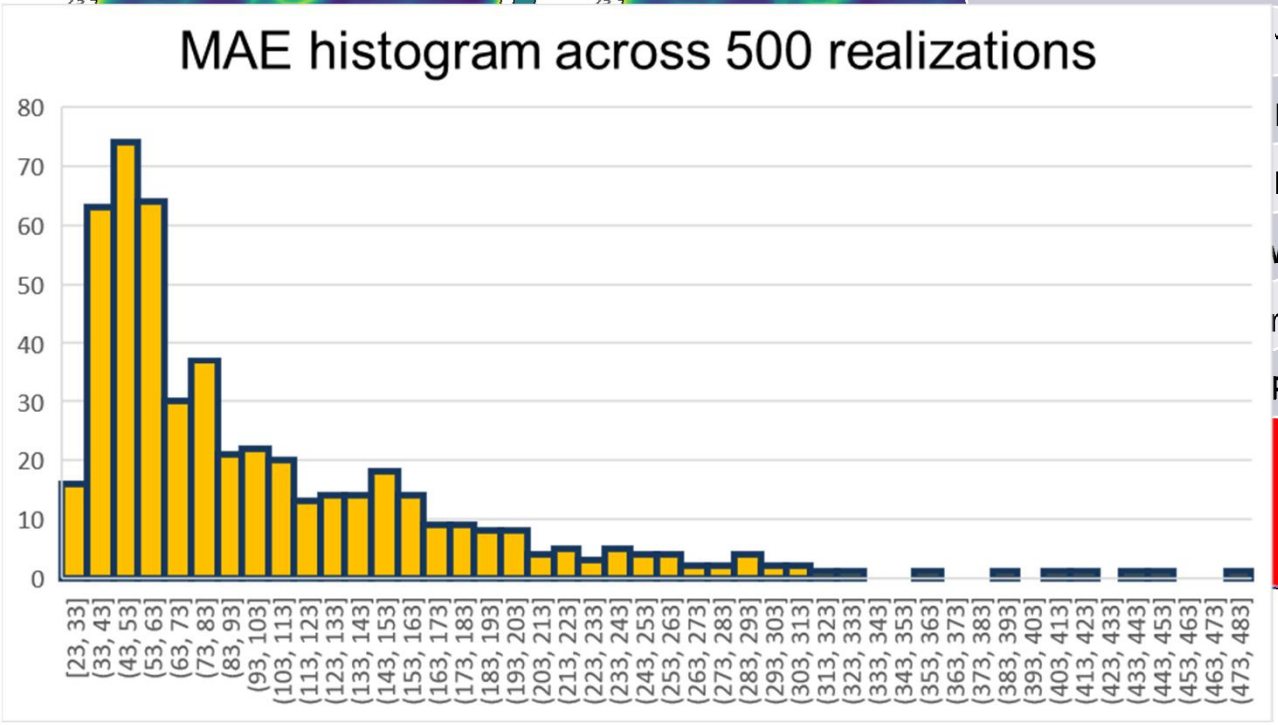

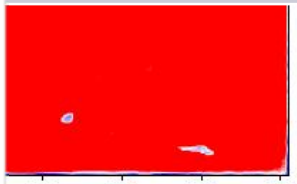

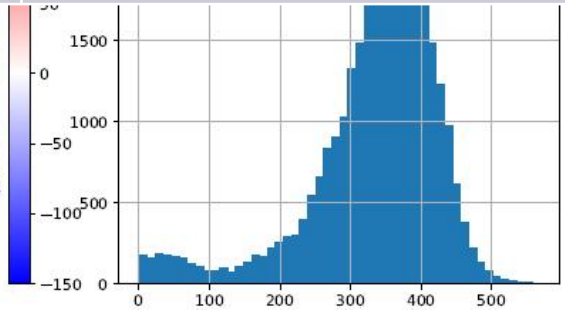

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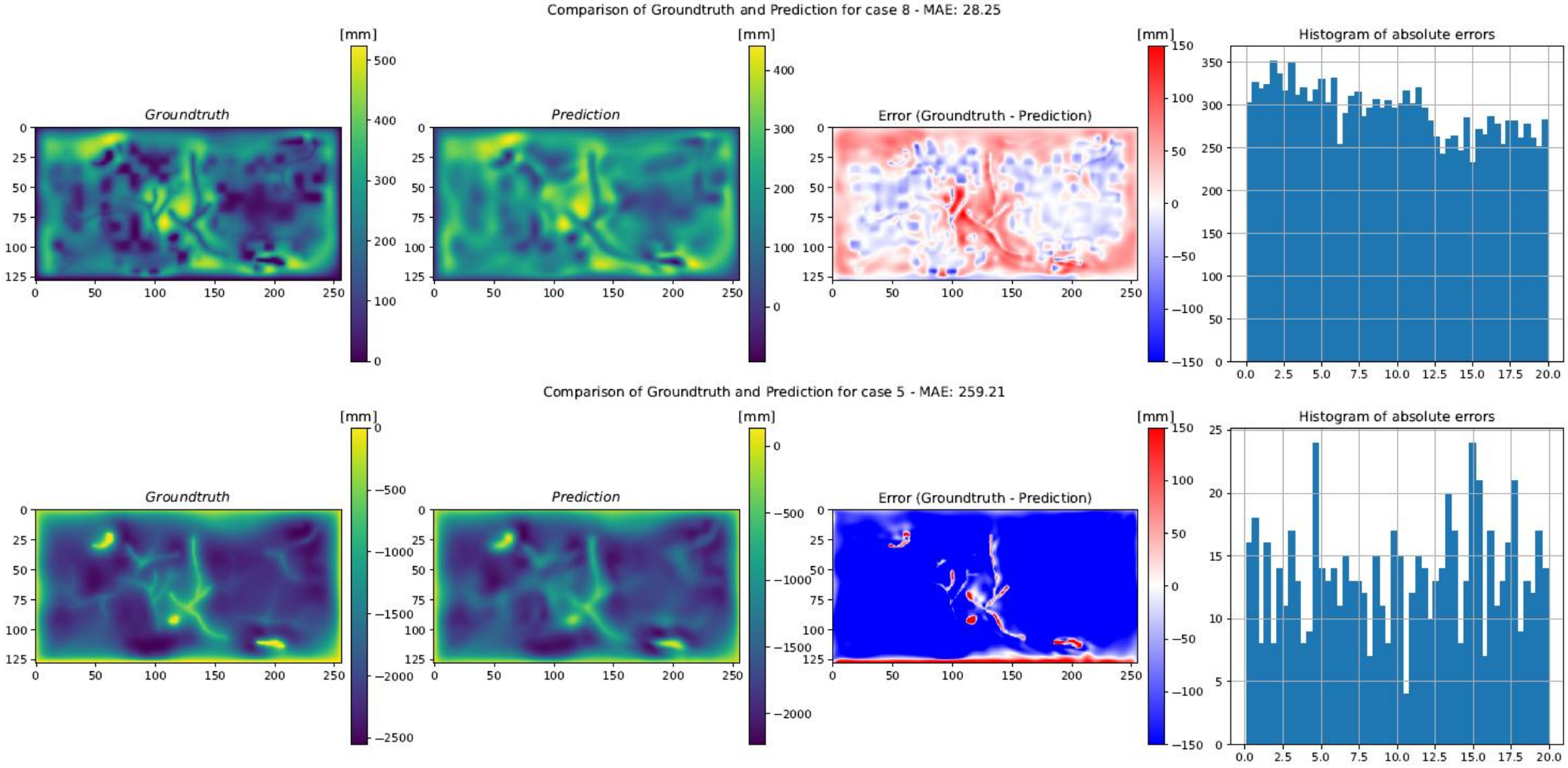

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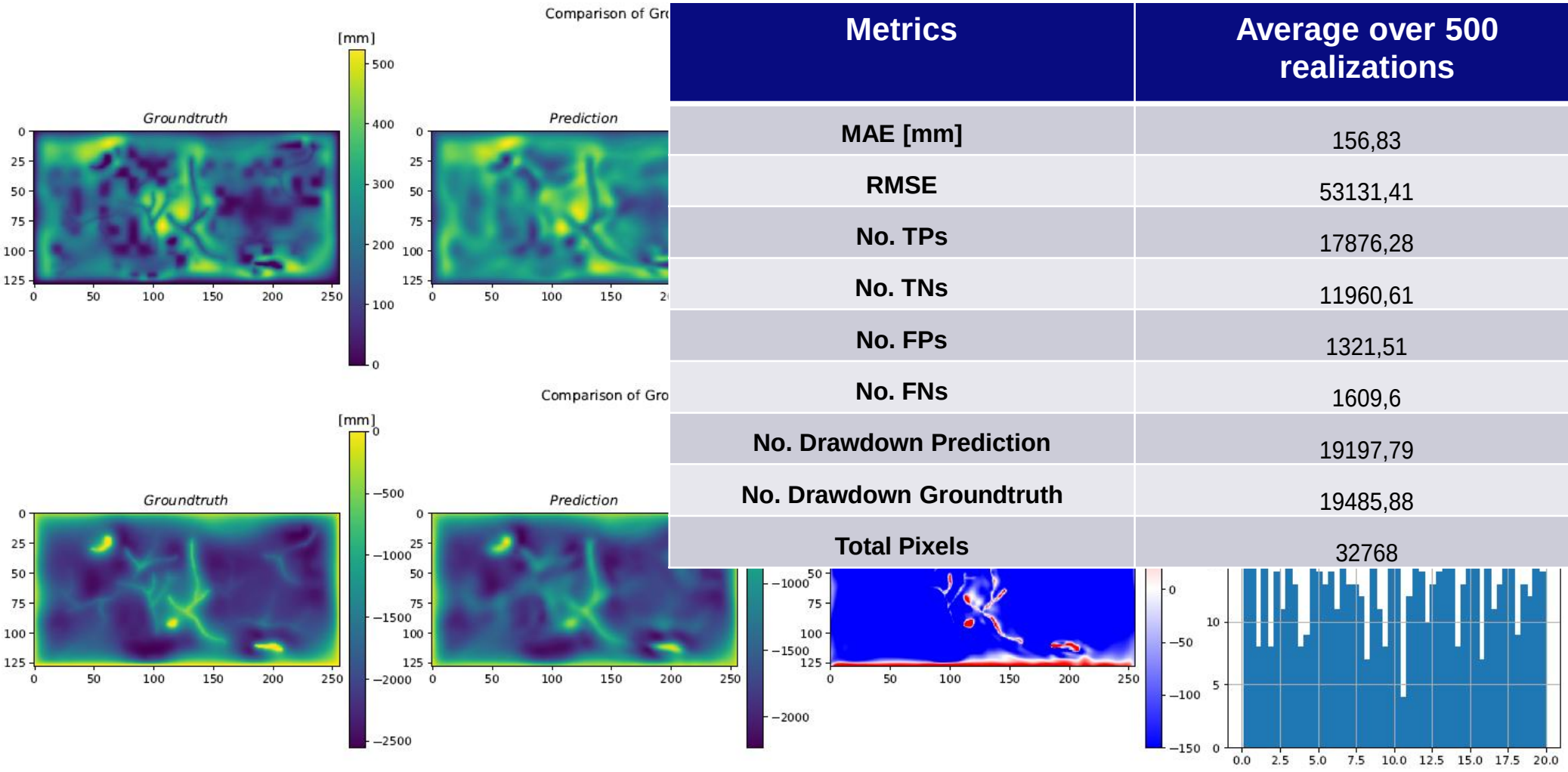
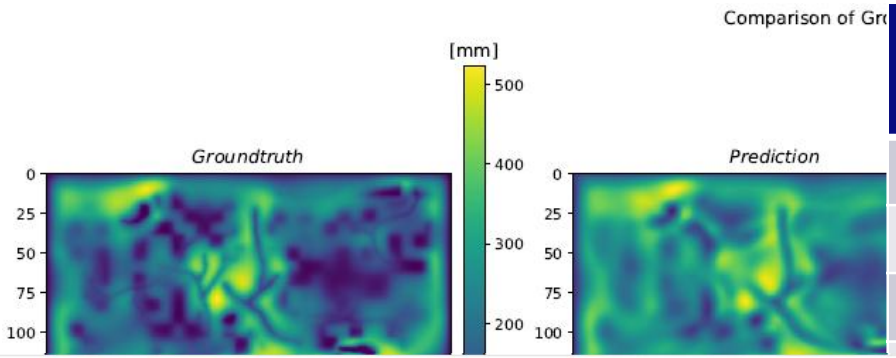


Metrics	Average over 500 realizations
MAE [mm]	156,83
RMSE	53131,41
No. TPs	17876,28
No. TNs	11960,61
No. FPs	1321,51
No. FNs	1609,6
No. Drawdown Prediction	19197,79
No. Drawdown Groundtruth	19485,88
Total Pixels	32768

Default DON Date No.4 visualizations



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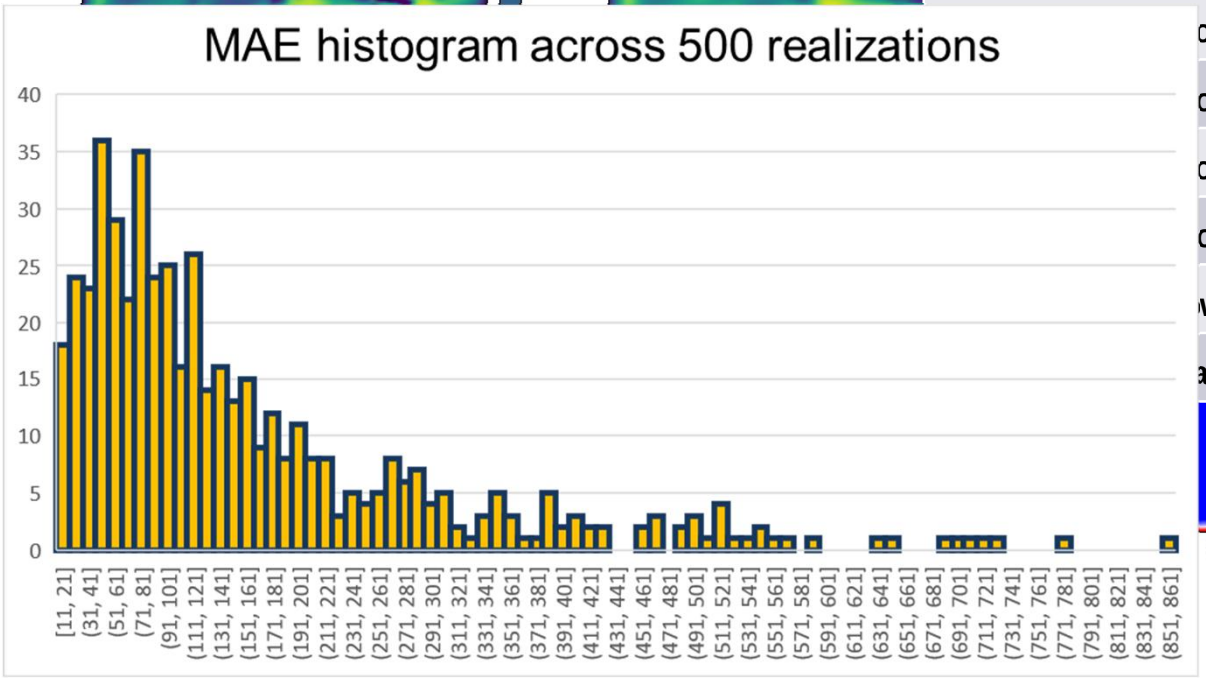
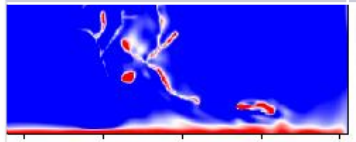
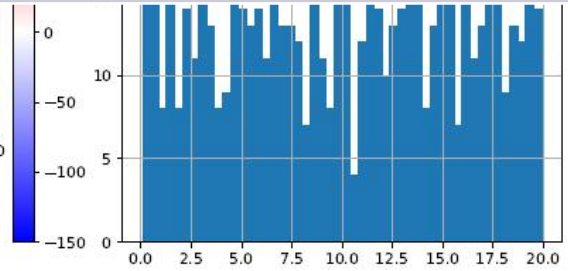






Deltares

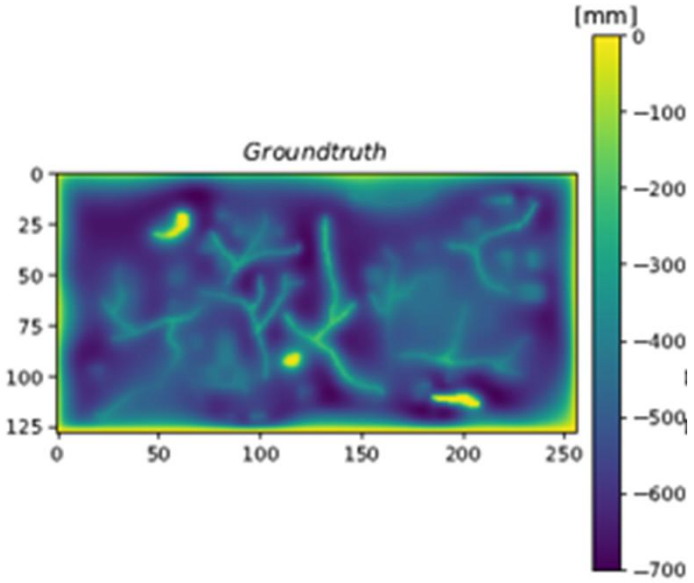
Prediction for Date No.7

Precipitation

ETp

184 days

01-10-2010



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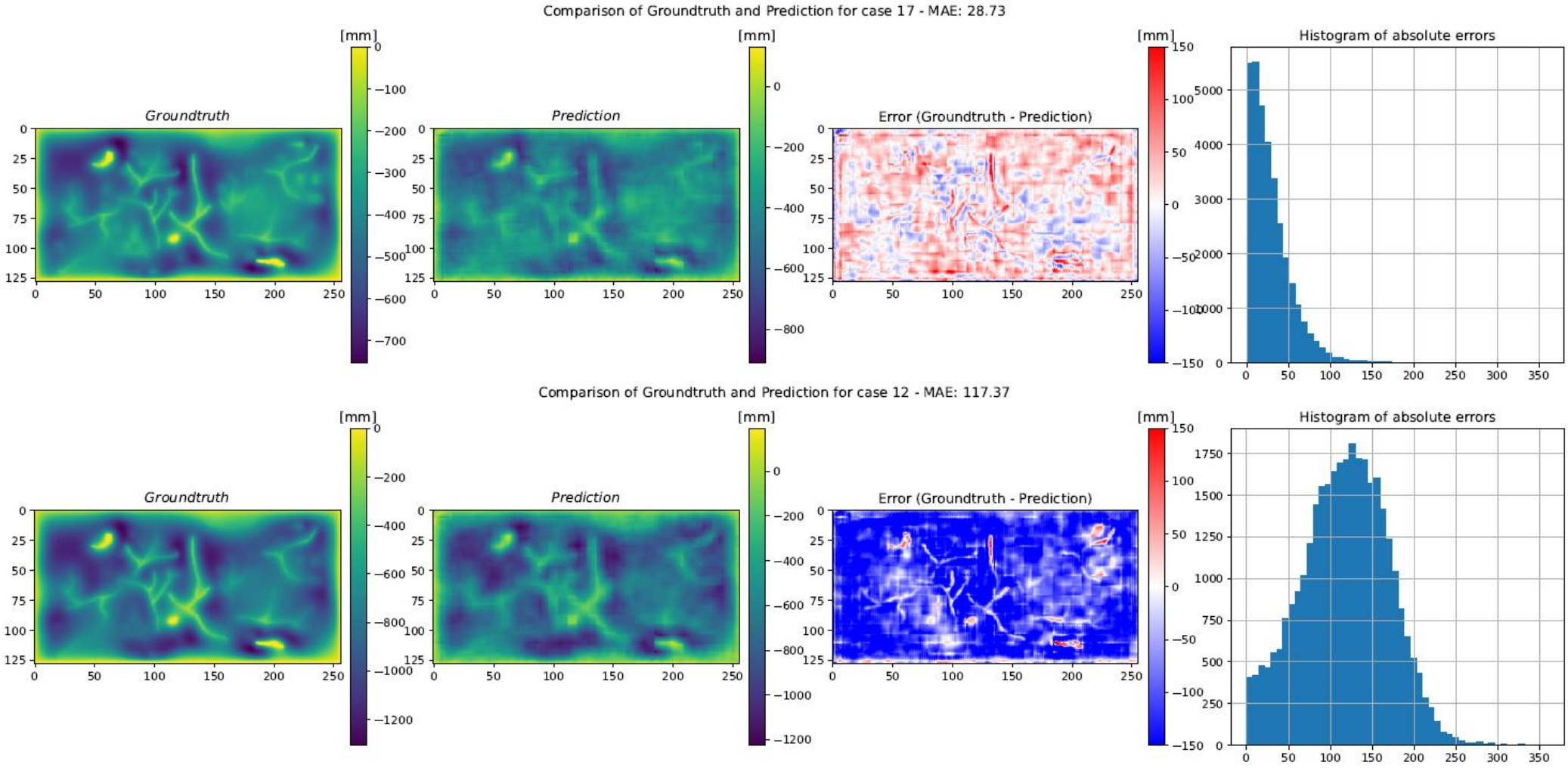
Encoder-Decoder Date No.7 visualizations



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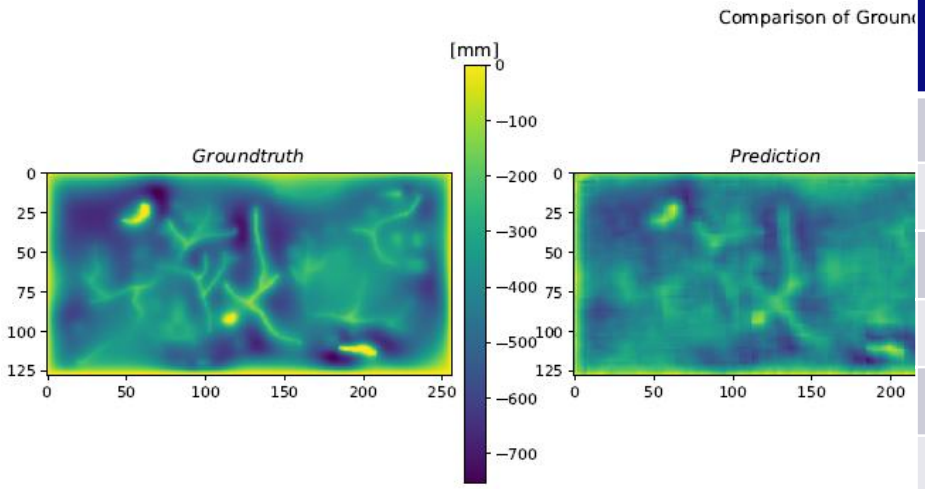
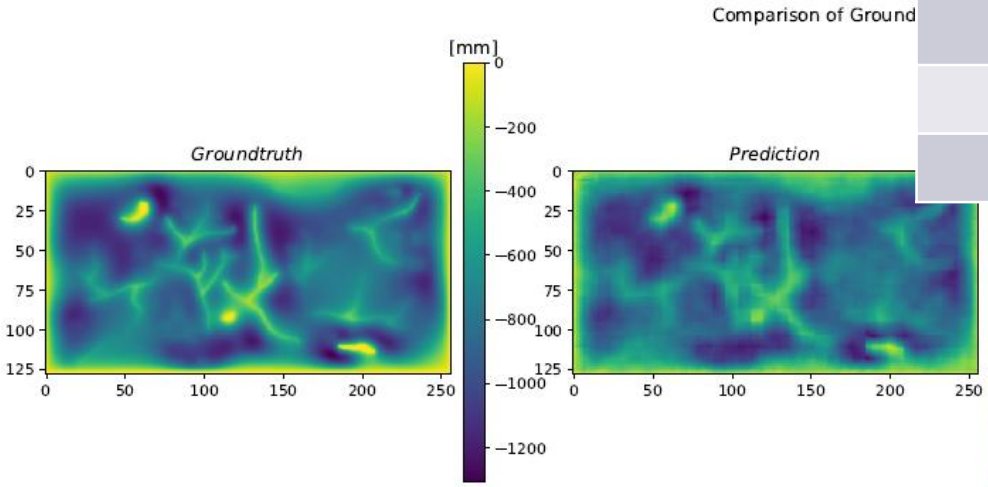
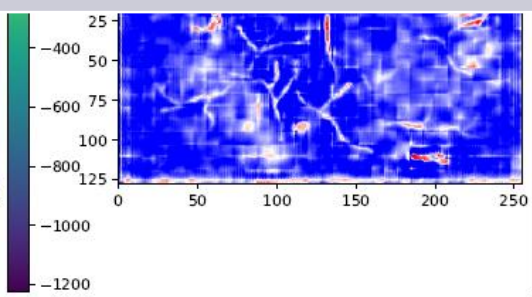
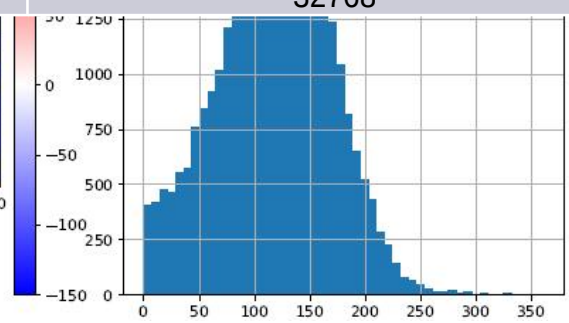




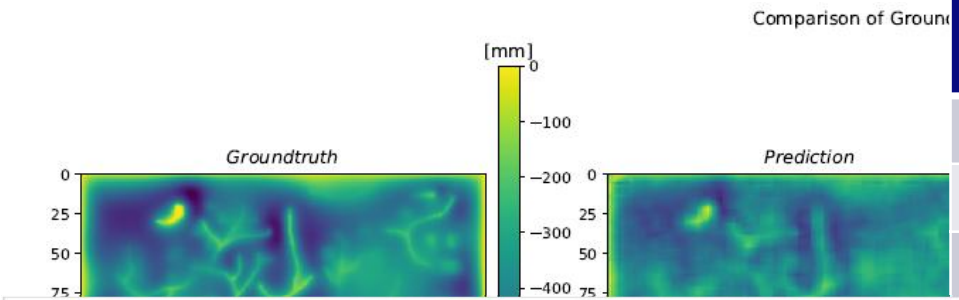




Metrics	Average over 500 realizations
MAE [mm]	86,98
RMSE	12942,24
No. TPs	18289,9
No. TNs	12457,4
No. FPs	946,852
No. FNs	1073,84
No. Drawdown Prediction	19236,75
No. Drawdown Groundtruth	19363,74
Total Pixels	32768

Deltares

Encoder-Decoder Date No.7 visualizations



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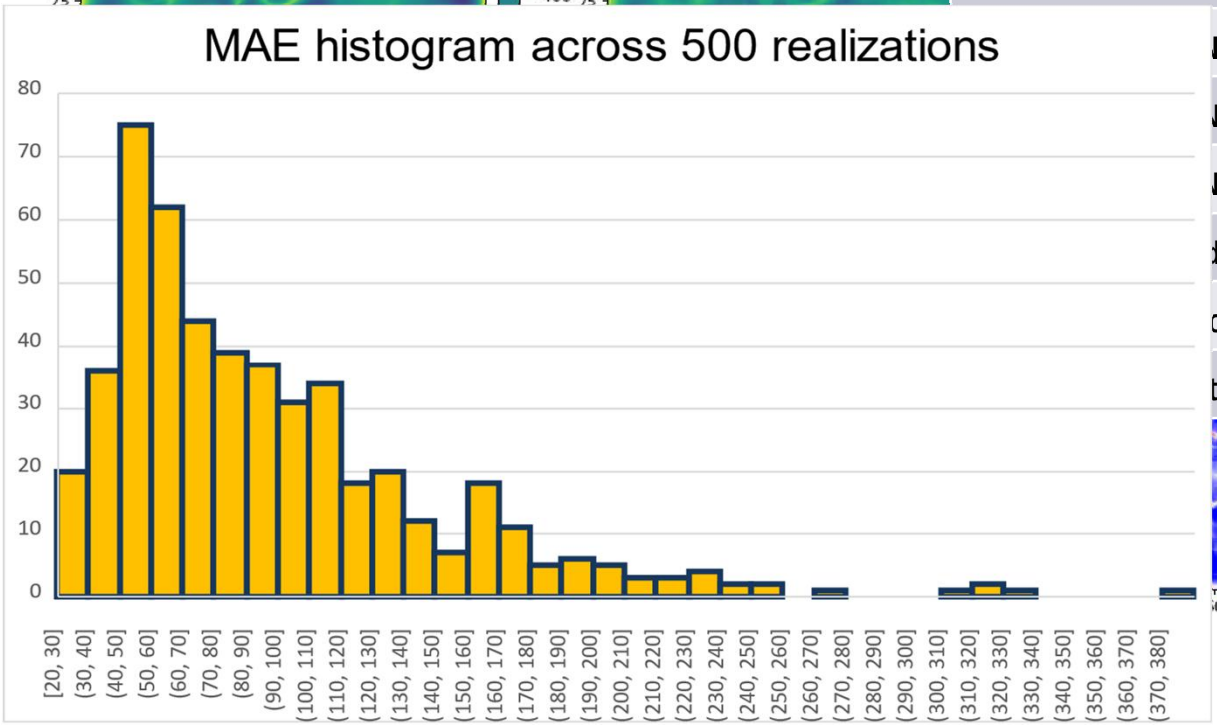
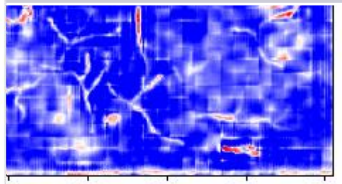
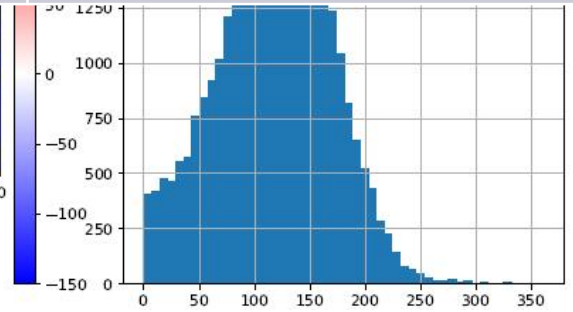
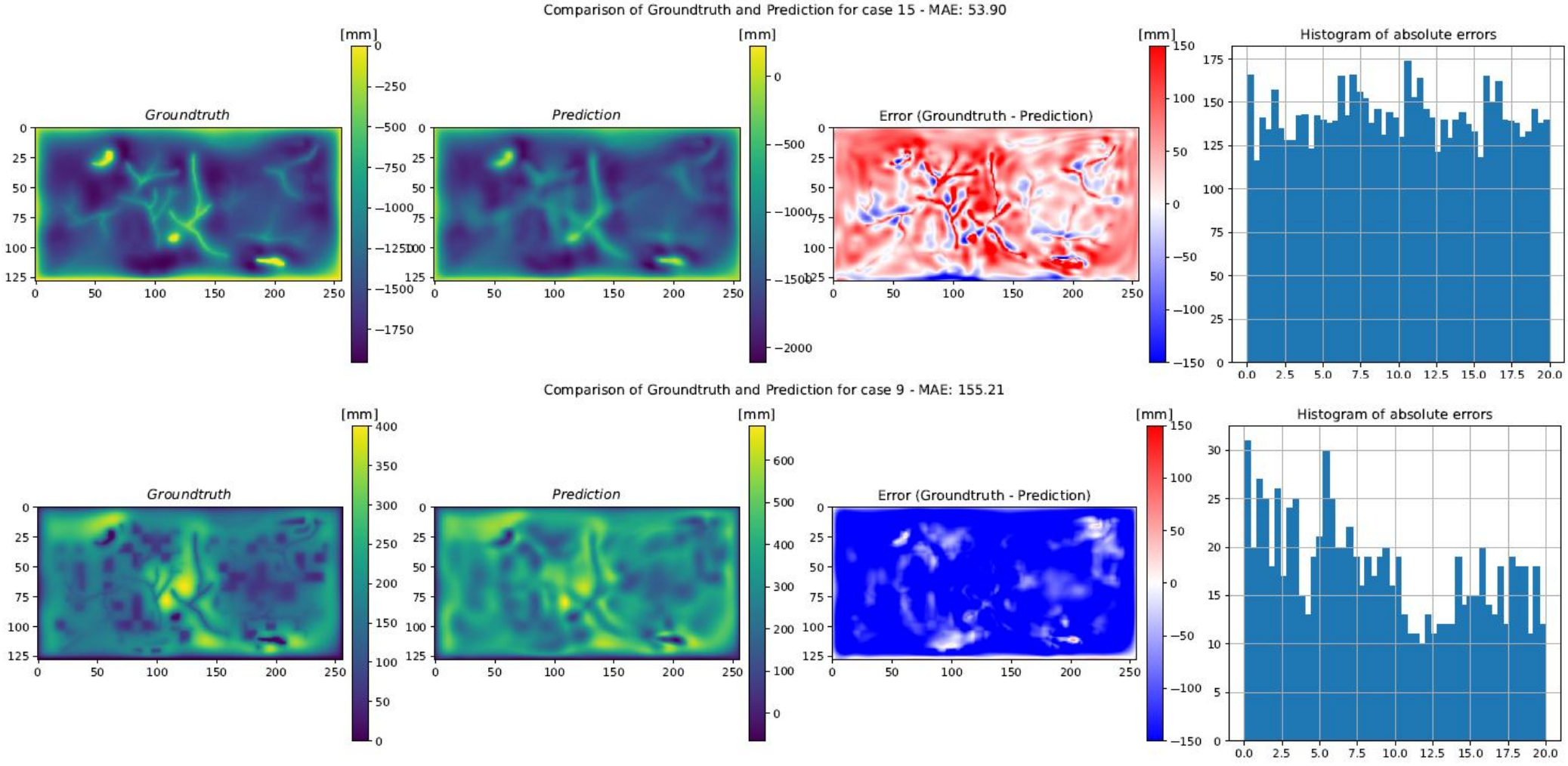






Deltares

Default DON Date No.7 visualizations



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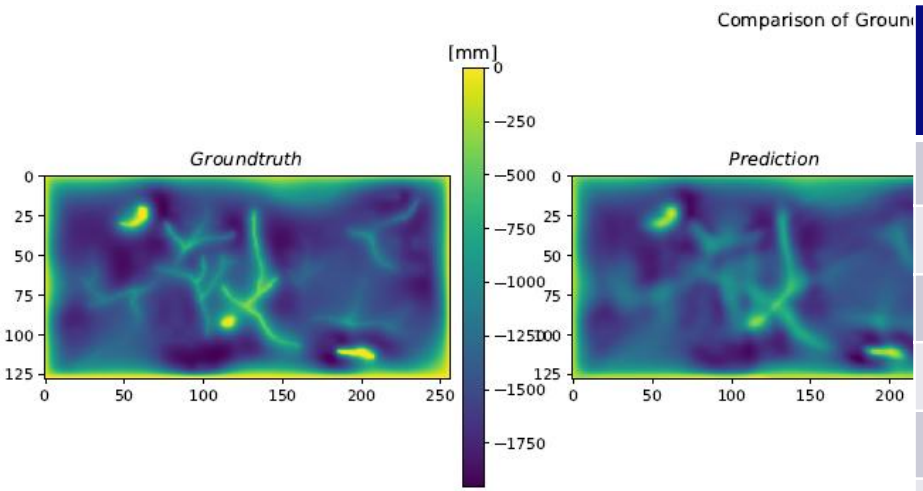
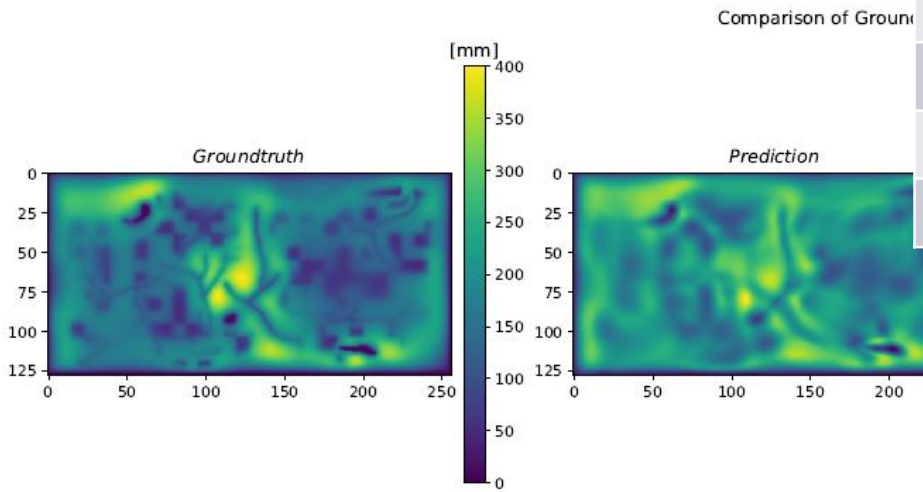
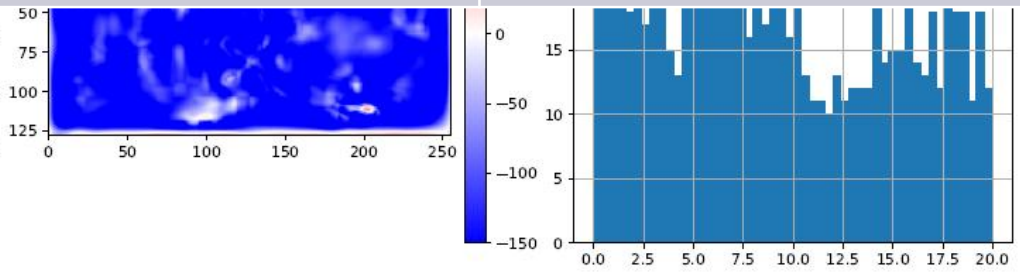




Metrics	Average over 500 realizations
MAE [mm]	137,11
RMSE	40789,82
No. TPs	18746,74
No. TNs	11909,96
No. FPs	1284,96
No. FNs	826,336
No. Drawdown Prediction	20031,7
No. Drawdown Groundtruth	19573,07
Total Pixels	32768



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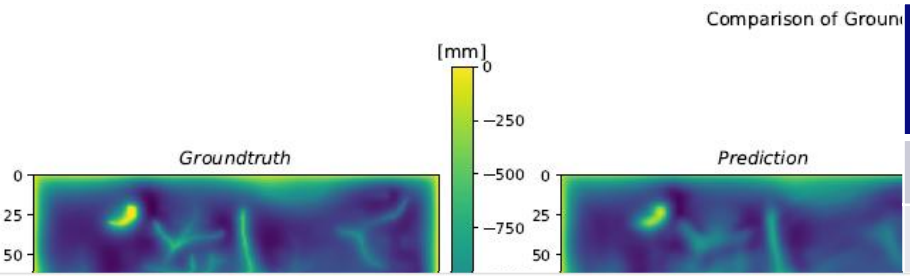

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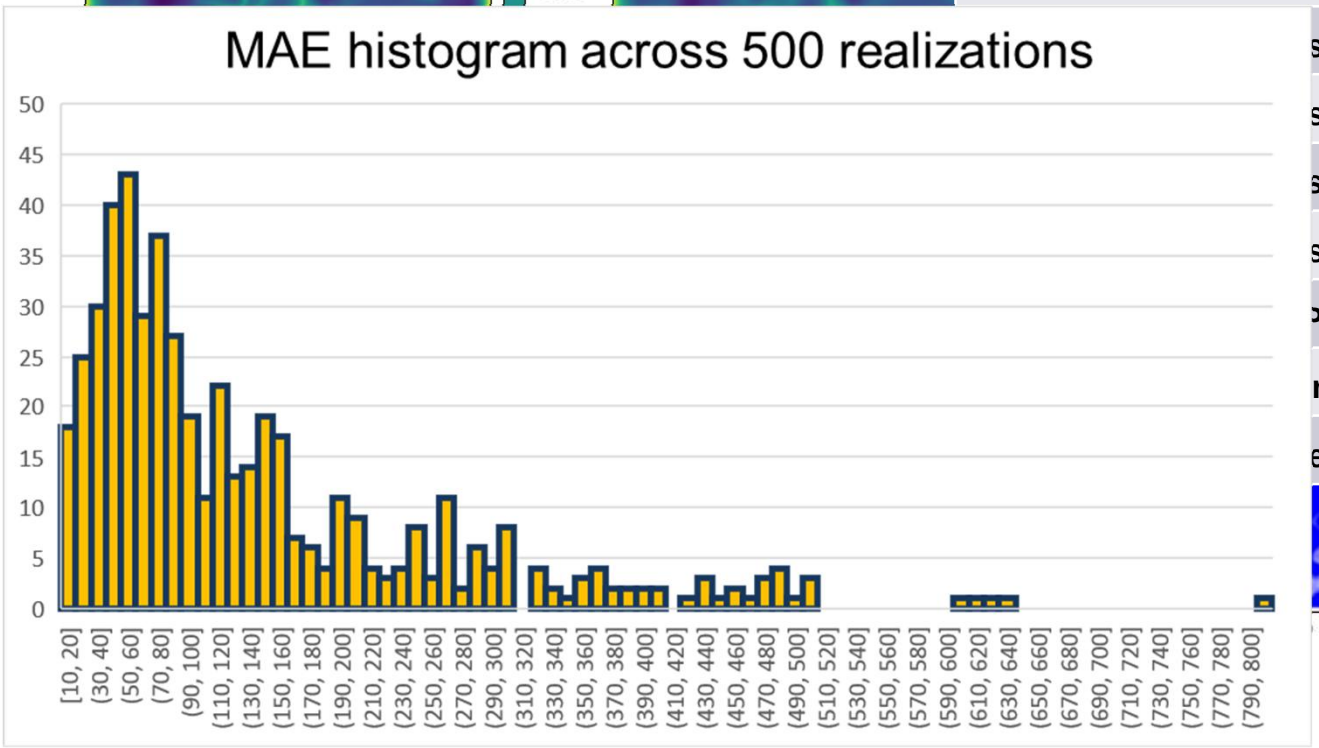

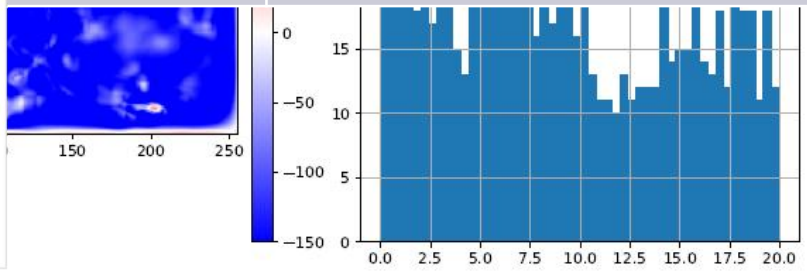

Deltares

Key takeaways

- FNO outperforms DONs in the GXG river network problem
- DON and Encoder-Decoder are close in the transient time-series problem, yet more complex methods to be tested
- DON could be more flexible when combining methods

Tussentijdse conclusies

1. In het algemeen leidt het trainen op verschillen/effecten tot betere resultaten dan het trainen op absolute waarden;
2. Tot nu toe geven vooral DON en (op enige afstand) FNO de beste resultaten[*1];
3. Het gebruik van Unet werkt niet goed met de “attention” versie[*2];
4. GAN levert geen veelbelovende resultaten. Deze laten we dan ook verder buiten beschouwing [*3];
5. Genereren van trainingsdata en training kosten veel tijd en hardware resources (financiën);

Opmerkingen tijdens het overleg:

**1): FNO doet ‘t inmiddels ook goed, zeker gezien het feit dat er tot nu toe minder tijd in de techniekontwikkeling is gestopt.*

**2): dat hangt van de casus af: het toevoegen van ‘attention’ helpt als het systeem verandert, dus bij een ‘moving well’ en een veranderend riviersysteem.*

**3): Jonathan wil nog niet stoppen met GAN’s: bij GAN’s is het gemakkelijker om de waterbalans of andere fysica toe te voegen.*

Deltares

Koffie / thee

Agenda

1. Opening + vaststellen agenda + mededelingen	09:30 - 09:35	(5 min)
2. Notulen, acties, update projectplan n.a.v. vorig overleg	09:35 - 09:45	(10 min)
3. Techniekontwikkeling: stand van zaken	09:45 - 10:45	(1 uur)
koffie / thee	10:45 - 11:00	(15 min)
4. Techniekontwikkeling: prioritering t/m februari 2024	**11:00 - 11:35**	**(35 min)**
5. Planvorming in-kind uren-bestedingen	11:35 - 11:50	(15 min)
6. Afspraken en volgend projectgroepoverleg	11:50 - 11:55	(5 min)
7. Rondvraag en afsluiting	11:55 - 12:00	(5 min)
Lunch	12:00 - 13:00	(1 uur)

4. Techniekontwikkeling: prioritering t/m feb 2024

Belangrijkste doelen/uitdagingen:

1. Ontwikkelde technieken ook toepassen voor de andere cases (cellen zonder kleur ‘geel’ maken)
2. Technieken zelf verbeteren / verdiepen, en alleen toepassen op de bestaande cases (van geel naar groen).
3. Head series transient
4. Meerdere input variabelen
5. Aanvullende output variabelen: flux en evaporation
6. Modelomvang
   - Vooral in tweede jaar
   - Nu bewustwording

4. **3.** **5.**

Input	Input type	Output effect		Head series transient	Output absolute		
		GXG effect	Head steady-state effect		Head prediction at T=t	Evaporation reduction	Flux (riv) effect
Moving well fixed Q	point	Vechtstromen	Vitens		HDSR		
Moving well varying Q	point		Vitens				
Kh value (kD-value)	raster		Vitens				
Kv value (c-value)	raster		Vitens				
Recharge (prec & evap)	series	Vitens?		HDSR, Vitens?	HDSR		
Drain elevation	raster	Vechtstromen					
River bottom elevation	raster	Vechtstromen	Vitens				
River bottom conductance	raster	Vechtstromen	Vitens				
River stage steady-state	raster	Vechtstromen; Zuiderzeeland (?)	Vitens		HDSR		
River stage transient	location; series or [start, period, strength]	RWS		Zuiderzeeland		Zuiderzeeland	Zuiderzeeland, RWS
River stage seasonal	2 rasters (or separate training summer / winter)	Vechtstromen				Zuiderzeeland	

4. Techniekontwikkeling: prioritering t/m feb 2024

2. Huidige technieken (generiek) verbeteren/uitbreiden - opties:

1. Testen van varianten van gebruikte technieken (b.v. default DON vs. continuous DON's);
2. Verbeteren van de loss function (op basis van statistische criteria);
3. Toevoegen van fysica aan de loss function (bijv. waterbalans/fluxtermen);
4. Verbeteren van de sampling technieken;
5. Onderzoek benodigde omvang trainingsdata in relatie tot vereiste nauwkeurigheid.

4. Techniekontwikkeling: prioritering t/m feb 2024

Bepalende factoren:

1. Tijd en hardware om invoer te genereren (beschikbare CPU, schijfruimte, RAM)
   Voorbeeld vereenvoudigd Vechtstromen model:
   - Dimensies: 256 x 256 x 10
   - Modelperiode: 10 jaar
   - Rekentijd circa 3 uur
   - 10000 samples op 32 cores: 39 dagen rekentijd
2. Tijd en hardware om modellen te trainen (beschikbare CPU, schijfruimte, RAM)
3. Nauwkeurigheid van de voorspellingen

4. Techniekontwikkeling: prioritering t/m feb 2024

Randvoorwaarden

- Financieel: stand-van-zaken:

Totaalbudget:	€ 886,379	
voorloopkosten + onvoorzien	€ 62,386	
uitbestedingen:	€ 146,400	
in-kind:	€ 92,900	
Deltares-deel:	€ 584,693	
Deltares-deel, per maand:	€ 24,362	
budget Deltares maart t/m 17 nov 2023:	€ 200,988	34%
realisatie Deltares maart t/m 17 nov 2023:	€ 234,354	40%

- Financieel, maar nu ook rekening houdend met toekomstige CPU/hardware-kosten + rapportage; hieronder 75 kEuro als rekenvoorbeeld, dit bedrag ligt allesbehalve vast. Punt is: trade-off inkoop CPU/hardwarekosten en mensuren voor techniekontwikkeling.

Randvoorwaarden

- Capaciteit / planning
- Aanlevering data

4. Techniekontwikkeling: prioritering t/m feb 2024

Randvoorwaarden

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- Aanlevering data

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	€ 584,693	
hardware:	€ 75,000	= ~ 4 maanden voltijds 'Panos'
artikel + rapportage:	€ 35,000	
budget Deltares maart t/m 17 nov 2023:	€ 474,693	
Deltares-deel, per maand:	€ 19,779	
realisatie Deltares maart t/m 17 nov 2023:	€ 234,354	49%

4. Techniekontwikkeling: prioritering t/m feb 2024

Een mogelijke volgorde van werken:

1. Ontwikkelen/implementeren techniek voor voorspellen van *tijdreeksen* van 2D grids, inclusief het opgeven van een initiële conditie;
2. Implementeren en testen van trainen met meerdere input variabelen;
   voorwaarde: de input variabelen die nog niet getest zijn eerst solo ‘doen’.
3. Techniekverbetering; vanaf wanneer kunnen we gaan kiezen?
4. Inschatting benodigde hardware capaciteit voor casus modellen (genereren trainingsdata en trainen);
5. Indien mogelijk aanvullende output variabelen (flux effect; evaporation reduction)

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koffie / thee	10:45 - 11:00	(15 min)
4. Techniekontwikkeling: prioritering t/m februari 2024	11:00 - 11:35	(35 min)
5. Planvorming in-kind uren-bestedingen	**11:35 - 11:50**	**(15 min)**
6. Afspraken en volgend projectgroepoverleg	11:50 - 11:55	(5 min)
7. Rondvraag en afsluiting	11:55 - 12:00	(5 min)
Lunch	12:00 - 13:00	(1 uur)

5. Planvorming in-kind uren-bestedingen

- Toewerken naar volgende fase (tweede jaar): ‘real-world’ casusmodellen
- Grotere rol van casushouders en adviseurs

Twee acties gevraagd:

1. Voor volgend overleg (januari) per casus met betrokkenen plan van aanpak maken met
   - Uitwerking van de casus
   - Rol-/taakverdeling mede in relatie tot beschikbaar budget
2. Vooruitlopend op casussen: beoordelen resultaten vereenvoudigde casusmodellen
   - Wanneer is resultaat goed genoeg?
   - Waar gaat het wel goed, waar niet?
   - Volstaat de invoerdata (ruimtelijke/temporele variatie, bandbreedte) die bij de training is gebruikt?

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7. Rondvraag en afsluiting	11:55 - 12:00	(5 min)
Lunch	12:00 - 13:00	(1 uur)

6. Afspraken en volgend projectgroepoverleg

Agenda

1. Opening + vaststellen agenda + mededelingen	09:30 - 09:35	(5 min)
2. Notulen, acties, update projectplan n.a.v. vorig overleg	09:35 - 09:45	(10 min)
3. Techniekontwikkeling: stand van zaken	09:45 - 10:45	(1 uur)
koffie / thee	10:45 - 11:00	(15 min)
4. Techniekontwikkeling: prioritering t/m februari 2024	11:00 - 11:35	(35 min)
5. Planvorming in-kind uren-bestedingen	11:35 - 11:50	(15 min)
6. Afspraken en volgend projectgroepoverleg	11:50 - 11:55	(5 min)
7. Rondvraag en afsluiting	**11:55 - 12:00**	**(5 min)**
Lunch	12:00 - 13:00	(1 uur)

7. Rondvraag en afsluiting

Lunch