Interpolation of tropospheric delays for high accuracy NRTK positioning

Francesco Darugna[1,2],
Martin Schmitz[1], **Steffen Schön**[2],
Jannes Wübbena[1]

[1]Geo++ GmbH, Garbsen
[2]Institut für Erdmessung Leibniz Universität of Hannover

Frankfurt, 17.10.2018

TREASURE
TRAINING RESEARCH AND APPLICATIONS NETWORK TO SUPPORT THE ULTIMATE REAL TIME HIGH ACCURACY EGNSS SOLUTION

Outline

- Objective and data-sets
- ZTD variation
- horizontal gradients
- ZTD interpolation
- results
- conclusions and future work

- the TREASURE project is a Marie Skłodowska-Curie Actions (MSCA) Innovative Training Network (ITN), funded through the European Union’s Horizon 2020 Research and Innovation Programme

- the project will concentrate on research that will pave the way for the development of a service that can ensure enhanced real-time high accuracy positioning

Objective and data-sets (1/2)

- investigation of **interpolation** of **zenith tropospheric delay**
- from the **literature**, **ordinary Kriging** interpolation and **inverse distance weighted least squares** are the **most implemented** interpolation techniques
- the rule of thumb **1:-3** between error in the interpolation of the ZTD and **error in the height** in the position domain
- ZTD interpolation is relevant for **high accuracy positioning**

Objective and data-sets (2/2)

GNSS data

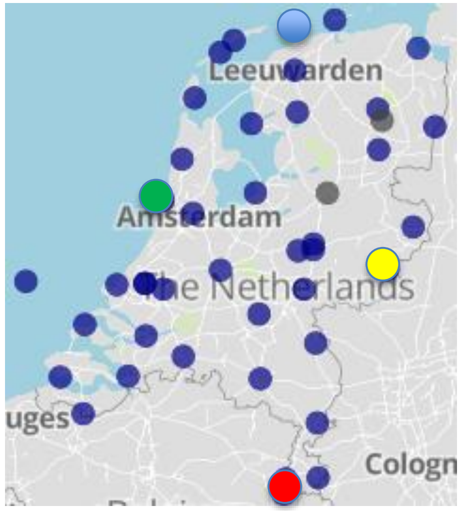
LGLN-SAPOS network	Kadaster network
Xavier windstorm October 2017	large weather fluctuations June 2017
Lower Saxony, Germany	The Netherlands
41 GNSS stations	36 GNSS stations
average distance: ≈ 45 km	average distance: ≈ 40 km
Rinex 2.1, 1s time-step	Rinex 2.1, 1s time-step

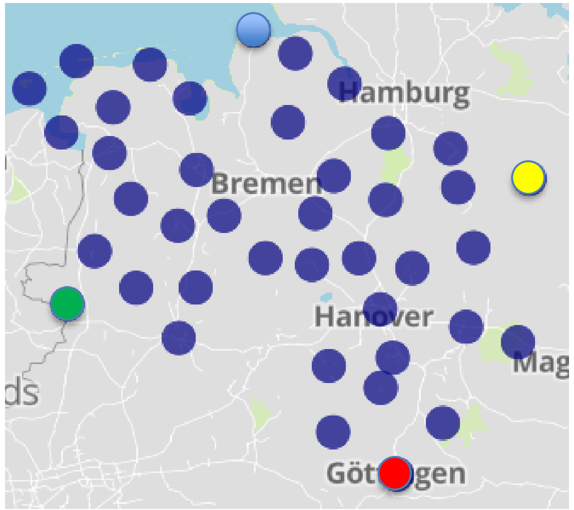
Numerical Weather Model data*

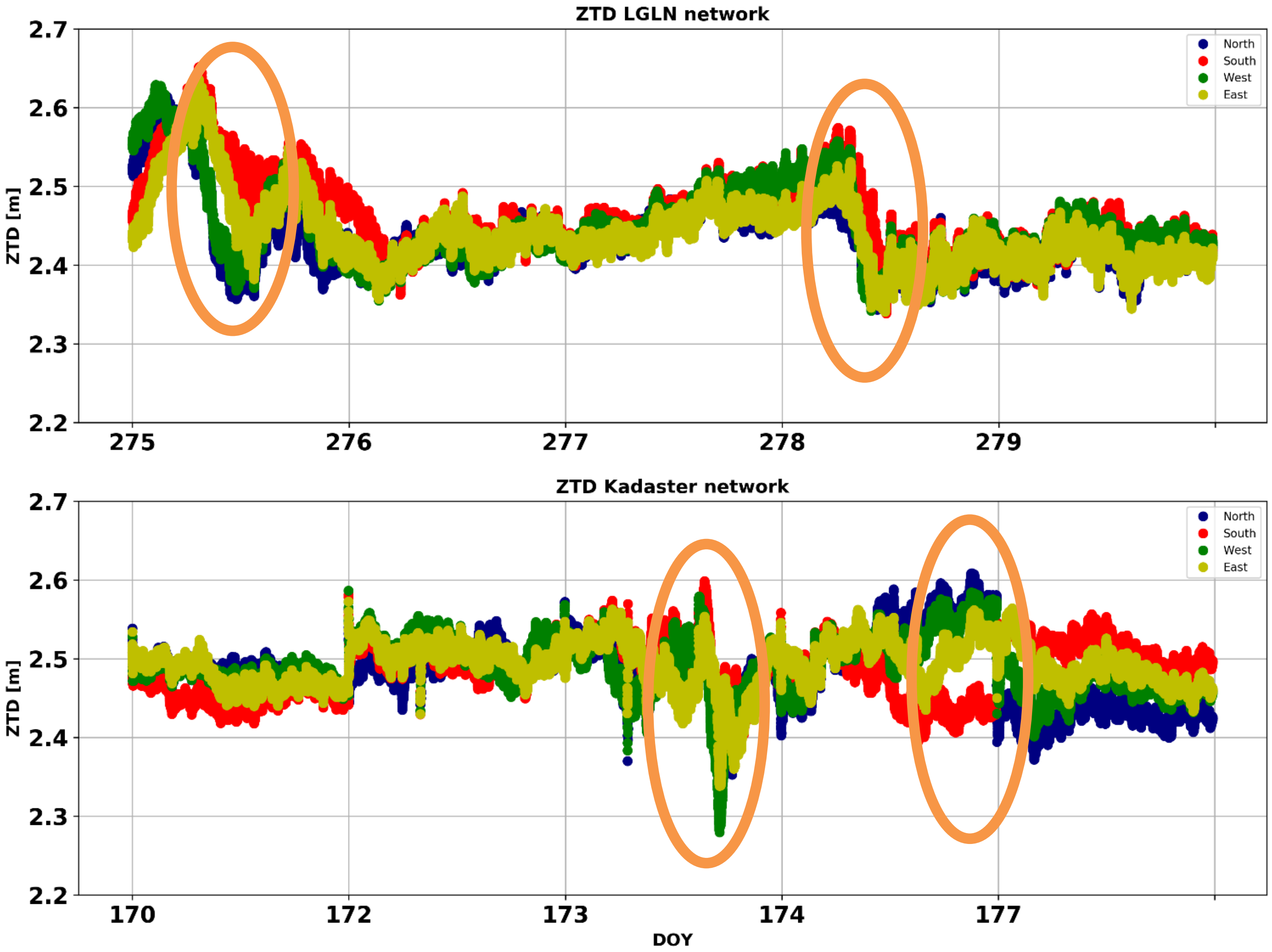
Global Forecast System (GFS)	Era-Interim
Xavier windstorm October 2017	large weather fluctuations June 2017
Lower Saxony, Germany	The Netherlands
time resolution: 3 h	time resolution: 3 h
spatial resolution: 0.25 deg	spatial resolution: 0.25 deg

* data provided by GFZ

ZTD variation



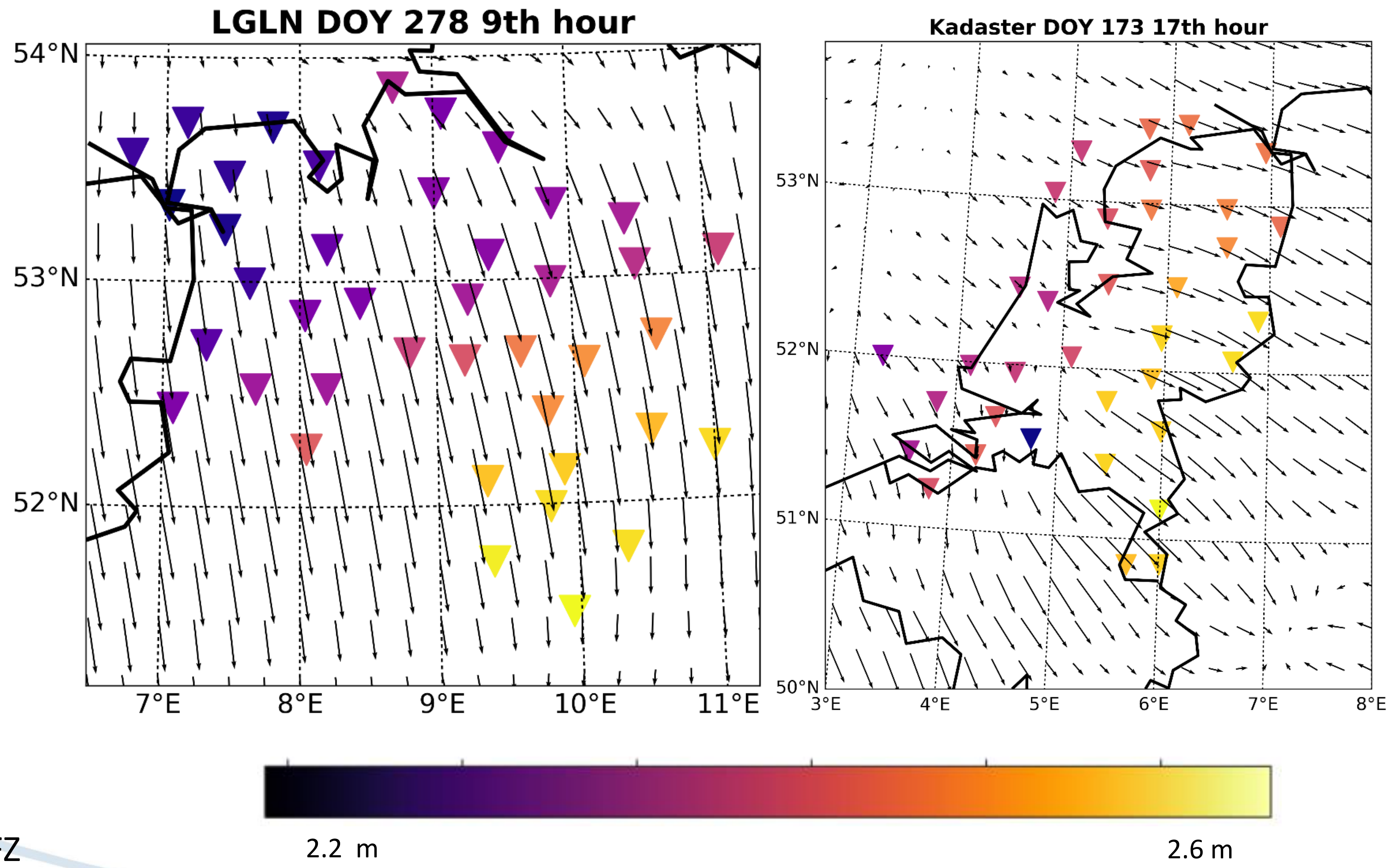




- Zenith total delay computed with the Geo++ software GNSMART
- **large spatial and temporal ZTD variations**
- the effect of the height was corrected, the plot refers to stations at **height = 0**

Horizontal gradients

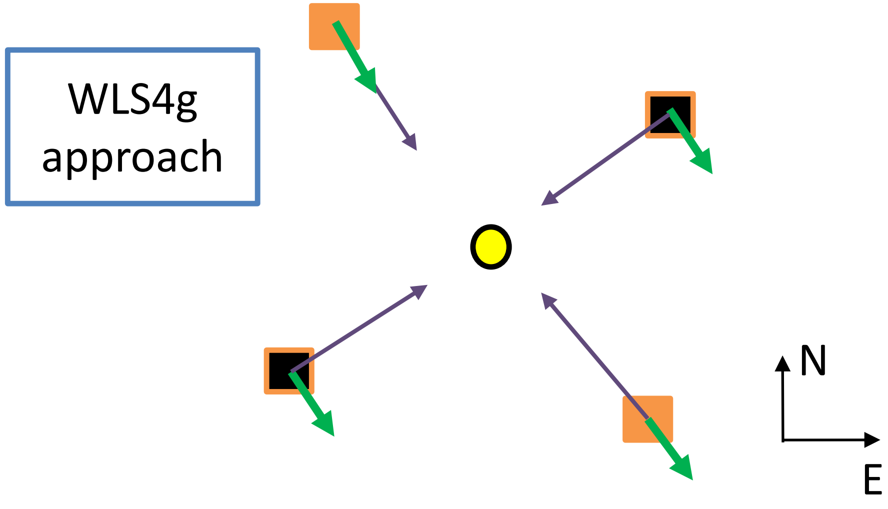
- ZTD computed from **GNSS** observations
- horizontal gradients retrieved from **NWM***
- **good agreement** between **ZTD variation** and **horizontal gradients** directions in both the days of large ZTD variations
- the variation of the ZTDs of the Kadaster data-set is more chaotic w.r.t. the LGLN data-set

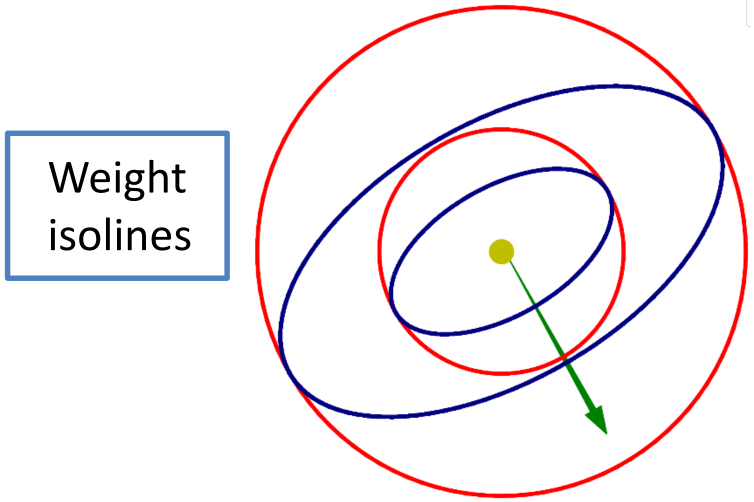


* data provided by GFZ

ZTD interpolation (1/2)

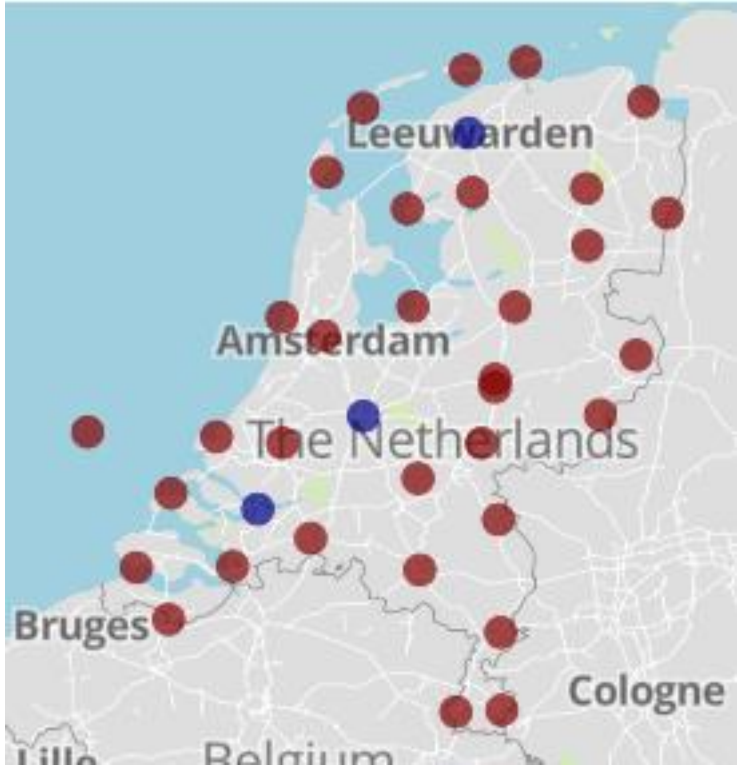
- Four different interpolation approaches have been investigated:
  - ordinary **Kriging** (OK)
  - **inverse distance weighted least squares** (IDW2)
  - **best fitting plane** determined from weighted least squares with weight depending on the inverse of the distance elevated to the power of four (WLS4)
  - best fitting plane determined from weighted least squares with weight depending on the distance elevated to the power of four giving more weight to the stations **perpendicular to the horizontal gradients retrieved from NWM** (WLS4g)

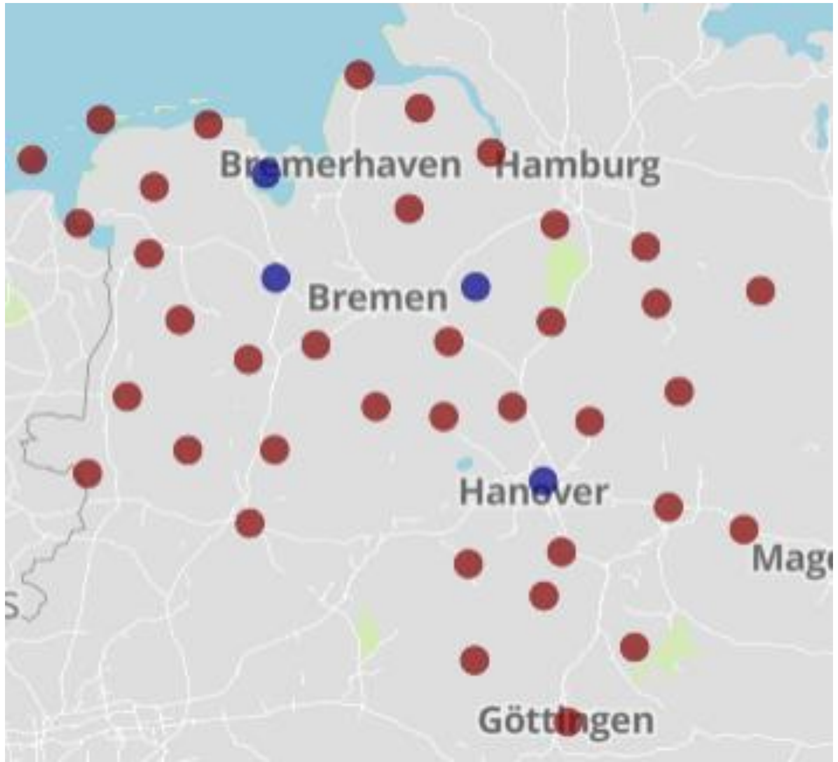




ZTD interpolation (2/2)

- the interpolation has been investigated considering **7 distinct stations**, 4 of the LGLN network and 3 of the Kadaster network
- these stations have been taken out from the networks and considered as **user locations**





Results

Results (1/4)

1. RMS of the interpolation error w.r.t. reference value computed with GNSMART for the LGLN network.

1 cm in the ZTD
→ 3 cm in the height

Technique	DOY 275 – 279 [mm]	DOY 275, hour 9 [mm]	DOY 278, hours 8-11 [mm]
IDW2	8	19	12
Kriging	7	8	10
WLS4	7	10	10
WLS4g	7	9	9

considering 4 stations

2. RMS of the interpolation error w.r.t. reference value computed with GNSMART for the Kadaster network.

2 mm in the ZTD
→ 0.6 cm in the height

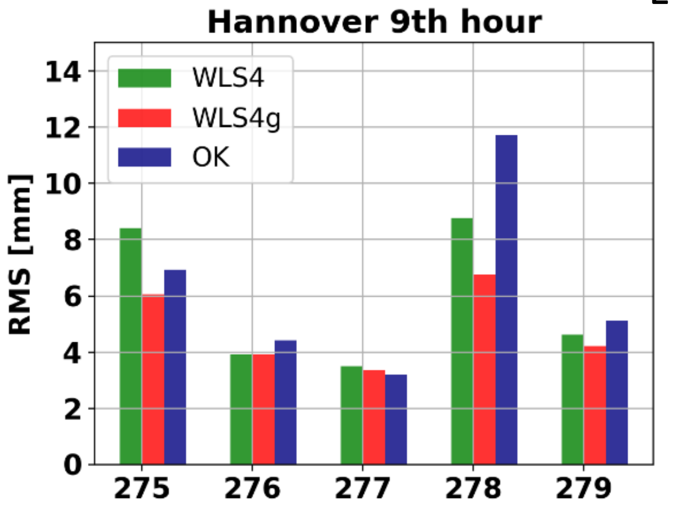
Technique	DOY 170-174, 177 [mm]	DOY 173, hour 17 [mm]	DOY 177, hours 15-18 [mm]
IDW2	39	24	9
Kriging	39	25	9
WLS4	39	24	9
WLS4g	39	25	7

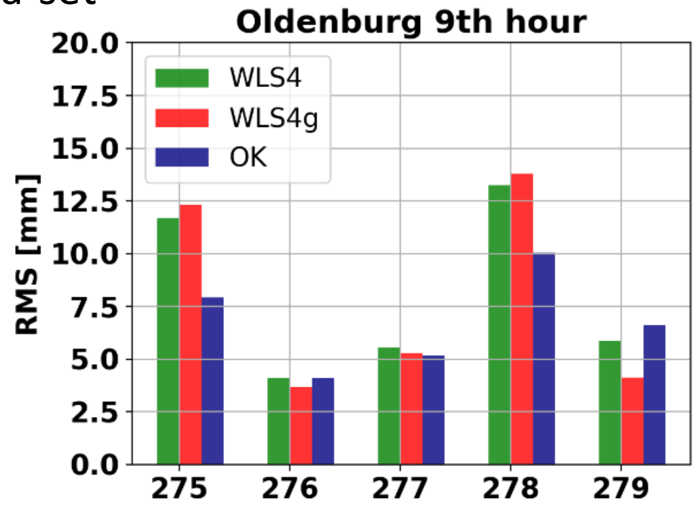
considering 3 stations

Results (2/4)

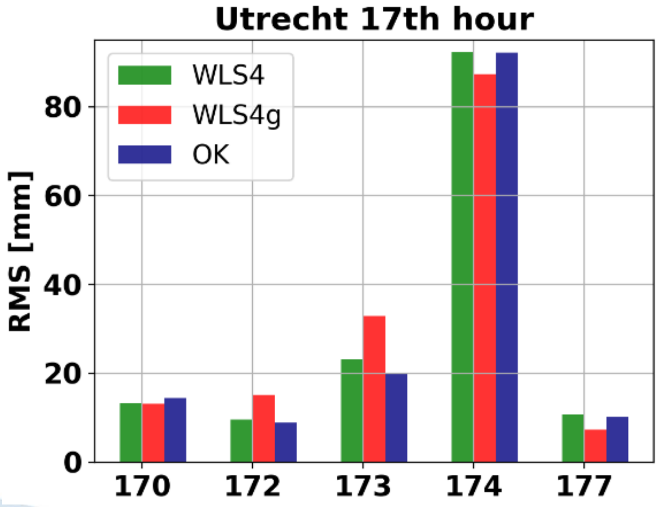
- in **60 %** of the cases shown the interpolation using the **gradients** gives the best interpolation quality
- the results depends also on the **position of the user** within the network w.r.t. the current location of the **weather event**
- **different interpolation quality** between LGLN and Kadaster data-sets due to strong weather fluctuations

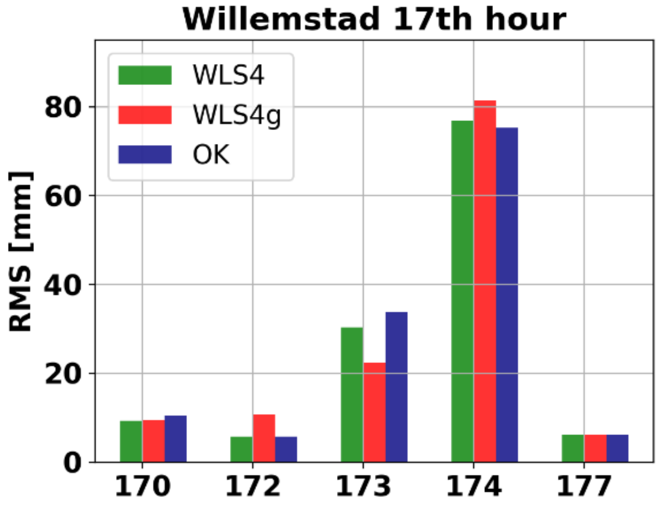
LGLN data-set





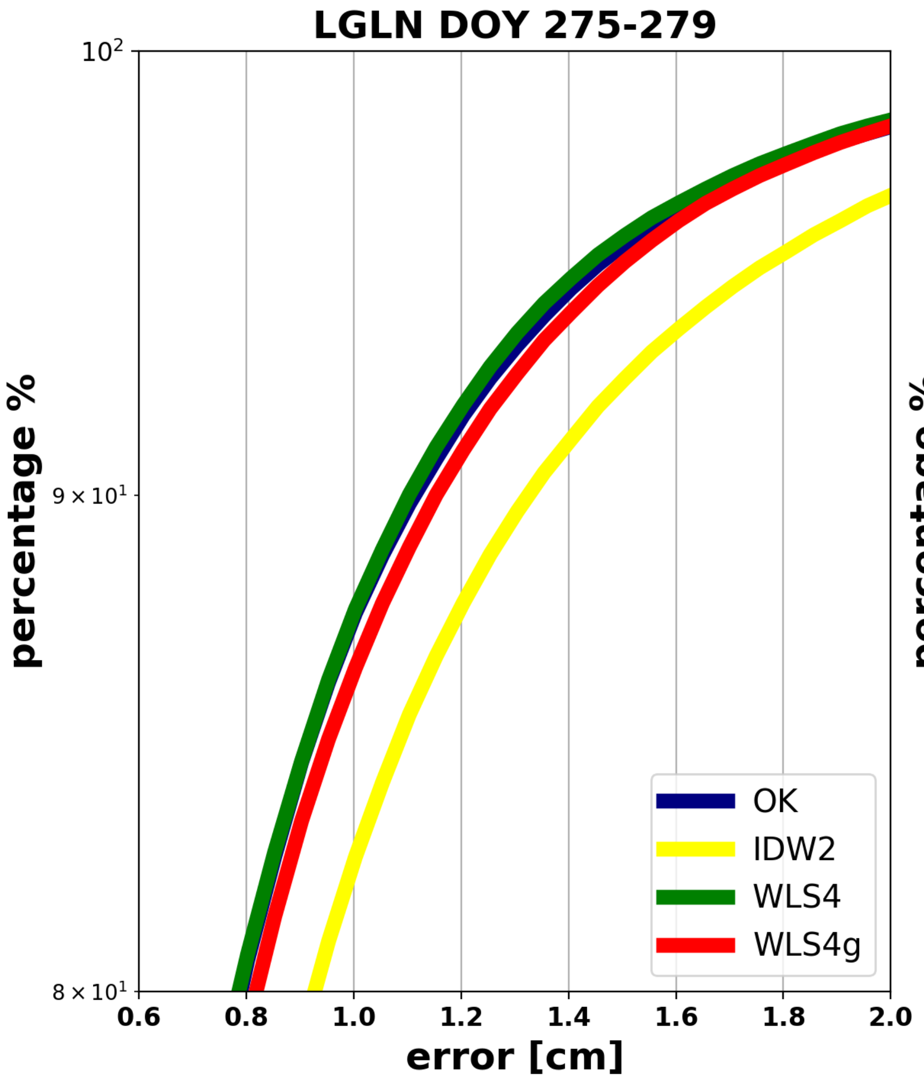
Kadaster data-set

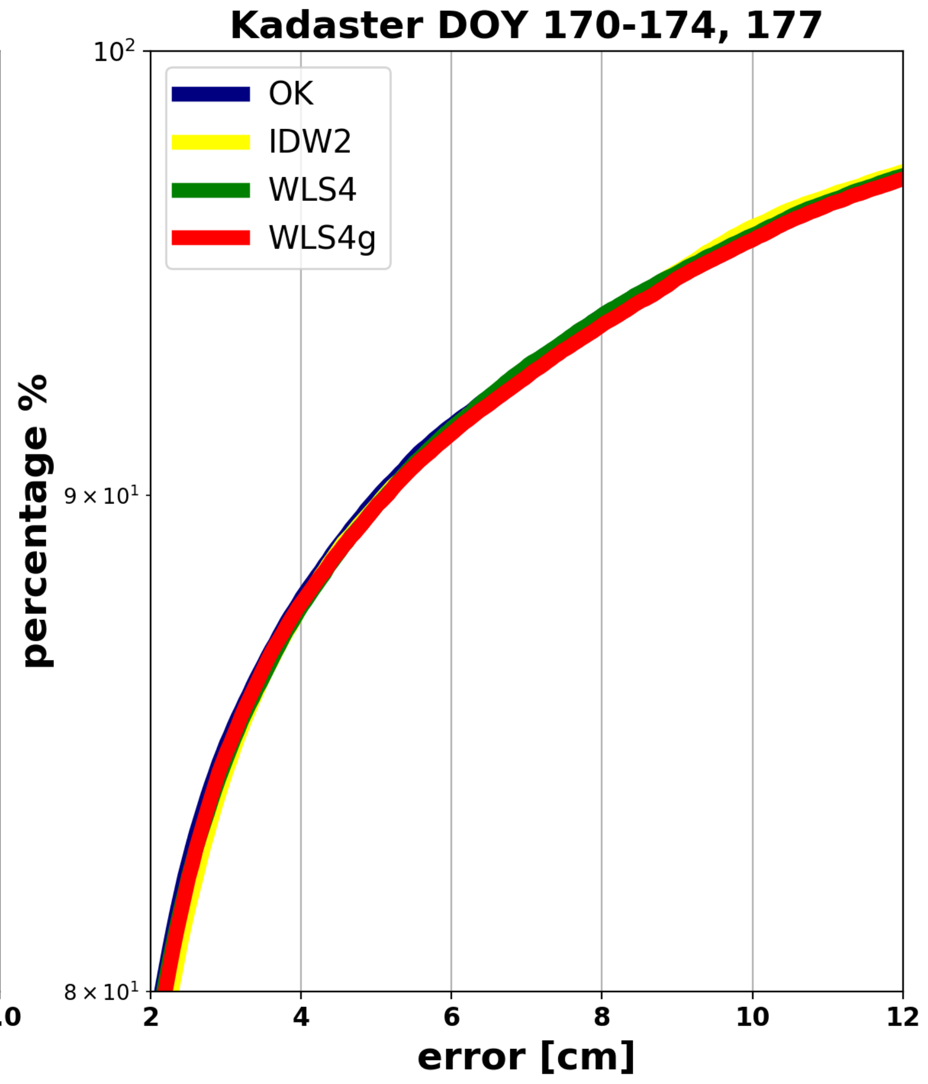




Results (3/4)

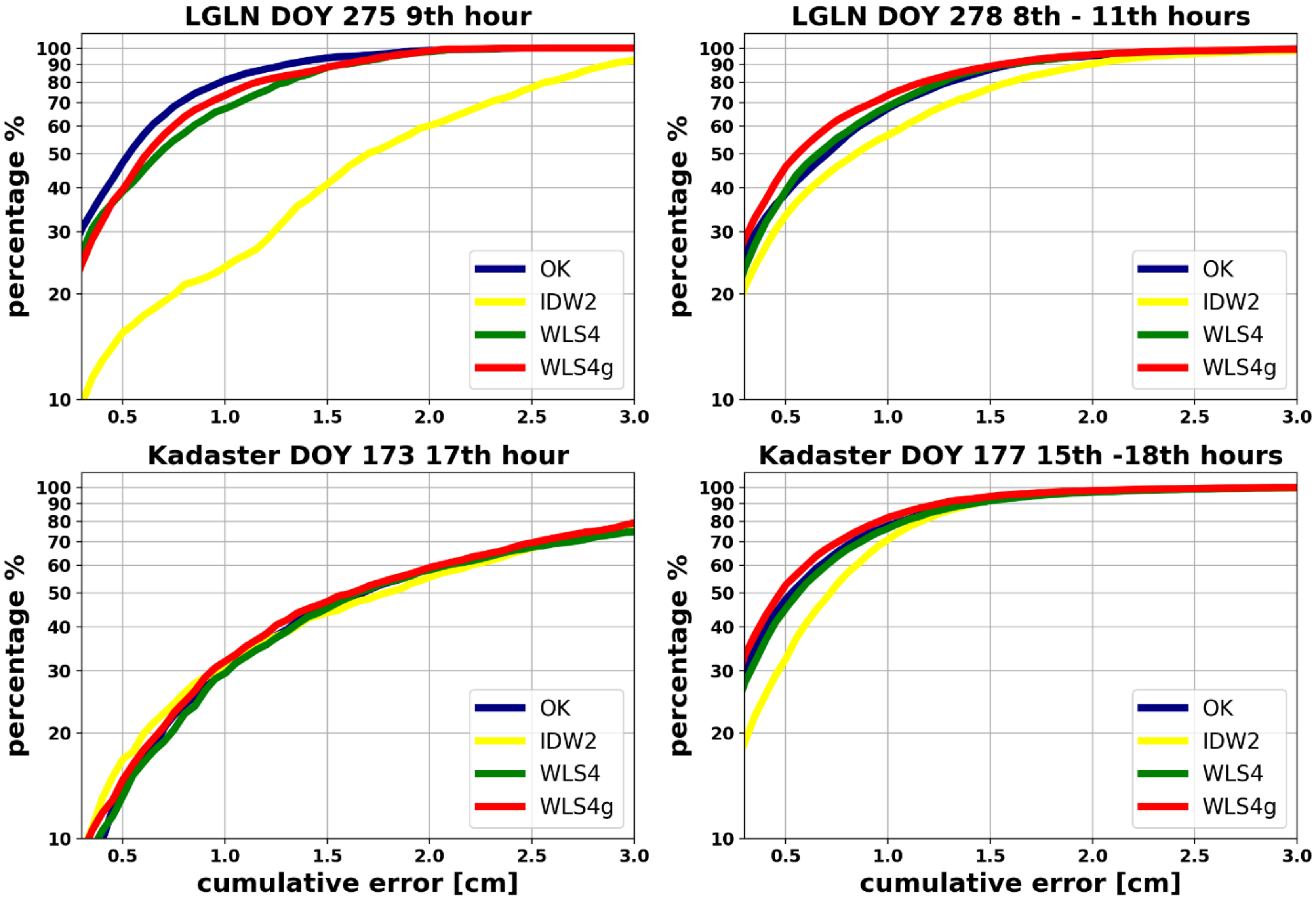
- for each data-set the **cumulative error** shows **similar performance** for the techniques used
- for the LGLN data-set the implementation of a different technique w.r.t. **IDW2** increases the number of small errors





Results (4/4)

- differences can be observed during particular hours involving **weather fluctuations**
- WLS4g marks an **increment** of the number of the **errors below 1 cm** w.r.t. IDW2



Conclusions and future work

Conclusions and future work

- the analysis indicates to **avoid inverse distance weighted least squares** for ZTD interpolation since the best fitting plane determined from weighted least squares and ordinary Kriging provide better performance

- during hours with **strong weather fluctuations** the use of the **gradients** (WLS4g) could **improve** up to **3 cm the error in the height** changing the error distribution

- further investigations are needed to define the criteria to decide **when to use** the WLS4g technique

- future work: implementation of WLS4g to see the effect in the **position domain** w.r.t. WLS4 in post-processing and a **real-time test** using horizontal gradients from NWM as external source

Thank you for your attention