Comparison DOWA and WINS50-data

Memo: Natalie Theeuwes, Jan Barkmeijer, Bert van Ulft and Ine Wijnant (KNMI)

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1. Introduction

1.1 DOWA data

In the Dutch Offshore Wind Atlas project (DOWA[1]) an 11-year wind climatology (2007-2018) was created. Regional numerical weather model HARMONIE-AROME and satellite and aircraft measurements were used to downscale global re-analysis ERA5 (Hersbach et al., 2020) to a dataset of hourly information on a 2.5 by 2.5 km grid spacing and up to 600 m height. This dataset is made available on the KNMI Data Platform. The satellite and aircraft measurements were assimilated in HARMONIE-AROME using a 3DVAR assimilation model. ERA5 provides the lateral boundary conditions. For DOWA, HARMONIE-AROME Cycle 40 (tag harmonie-40h1.2.tg2) was used, referred to as HARM-CY40 in the rest of the memo. All information on the DOWA can be found on the project website: Home | Dutch Offshore Wind Atlas.

1.2 WINS50 data

One of the aims of the WINS50 project[2] is to extend the DOWA with 3 years: 2019, 2020 and 2021. In order to create a homogeneous dataset, changes in method should be avoided, but we ran into problems with the HARM-CY40 version that was used for making the DOWA. From September 2019 HARM-CY40 was no longer able to assimilate[3] the German SYNOP measurements and we were forced to use a newer version of the HARMONIE model with a number of different parameter settings: HARMONIE-AROME Cycle 43 (tag harmonie-43h2.1) which we will refer to as HARM-CY43 in the rest of this memo.

The HARM-CY43 model version as described here, will also be used for the WINS50 data products that include the effects of (offshore) wind farms. For more information on the project we refer to the website www.wins50.nl.

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[1] The DOWA project is executed by the project partners 'ECN part of TNO', Whiffle and KNMI and supported with Topsector Energy subsidy from the Ministry of Economic Affairs and Climate Policy.

[2] The WINS50 project is executed by the project partners Whiffle, TU Delft and KNMI and supported with Topsector Energy subsidy from the Ministry of Economic Affairs and Climate Policy.

[3] Assimilation is a term used in atmospheric modelling and refers to using measurements for the initialization of the weather model.

1.3 Aim of the memo

This memo is about the consequence of having to use HARM-CY43 instead of HARM-CY40. The DOWA (HARM-CY40) is extensively evaluated (Publications | Dutch Offshore Wind Atlas) and proved very accurate. So the aim is to minimize the differences with the DOWA. To assess this, we compared HARM-CY40 and HARM-CY43 which are both available for January until and including September 2019. We also compared HARM-CY40 and HARM-CY43 to measurements (wind speed measurements at KNMI stations and wind and temperature measurements at the Cabauw tower).

The main differences between HARM-CY40 (DOWA), its predecessor KNMI North Sea Wind (KNW) Atlas and its successor HARM-CY43 (WINS50) are summarized in Appendix 1.

2. Comparing DOWA and WINS50 climatology

In order to make the difference between DOWA and WINS50 climatology as small as possible we changed some settings in the HIRLAM-default version of HARM-CY43[4] (see table below). So if we refer to HARM-CY43 in this memo, it is with XRIMAX 0.2 and XSCALE_H_TREE 0.658, not with the Dutch default settings.

	Dutch Offshore Wind Atlas 2007-2018 (DOWA) based on HARM-CY40	**WINS50 2019-2021 based on HARM-CY43 (tag harmonie-43h2.1)**	**Settings in HIRLAM-default version of HARM-CY43 (tag harmonie-43h2.1.1)**
Setting XRIMAX (*)	0	0.2	0
XSCALE_H_TREE (**)	--	0.658	1
Resolution ECOCLIMAP (surface data)	1 km	Second generation 300m	Second generation 300m

(*) The Richardson number indicates whether the atmosphere is stable (RI > 0), neutral (RI = 0) or unstable (RI <0). XRIMAX is a limitation in RI-number in surface-exchange calculations. XRIMAX = 0 means that surface exchange in stable conditions uses the stability calculations of neutral conditions. In other words: the higher XRIMAX (effect gets smaller > 0.1), the more physically accurate the temperature, humidity, and wind gradients are calculated near the ground in stable conditions. If XRIMAX = 0 a stable temperature profile near the ground is modelled as a neutral profile and surface exchange is overestimated. See also Appendix 2.

(**) In order to solve the problems with the new ECOCLIMAP [Faroux et al., 2013] version in HARM-CY43, LFAKETREE and XSCALE_H_TREE were introduced. In HARMONIE we distinguish between 'open land' and 'forest' patches. With LFAKETREE 'on' trees can be added to 'open land' patches. It is possible to choose on how much of the 'open land' patch there are trees (in %) and how high these trees are (in m). This is a way to increase the surface roughness of the 'open land' patch. For WINS50 10% of each 'open land' patch is filled with 10m high trees. Tree height is scaled with XSCALE_H_TREE in 'forest' patches.

[4] All countries choose their own settings. For more info on the settings of the Dutch operational version of HARM-CY43 we refer to https://hirlam.org/trac/wiki/ReleaseNotes

2.1 Comparing DOWA and WINS50 climatology at 10 m height

When comparing the wind measurements at 10 m height in September 2019 for 88 (figure 1.1) or 87 (figure 1.2) Dutch KNMI stations combined to HARM-CY40 (+3h forecast) and HARM-CY43 (+3h forecast), it becomes clear that the main difference occurs for the evening and night: HARM-CY43 overestimates the wind at 10m height and HARM-CY40 gives a slight underestimation. With XRIMAX set to 0.2 in the HARM-CY43 simulation, the stable stability functions used limit the amount of drag at the surface, leading to an overestimation of the night-time wind speed. By changing XRIMAX in HARM-CY43 to the Dutch default of 0 the difference with the measurements becomes smaller, but figure 1.3 shows that this also results in an incorrect night-time temperature gradient close to the surface (at Cabauw). By not using the stable stability functions during stable conditions the temperature gradient is around zero (as for neutral conditions).

When comparing the wind speed measurements at 10 m height for the 9 months when HARM-CY40 (DOWA) and HARM-CY43 (WINS50) were both available (January up to and including September 2019) it becomes clear that the difference is much higher over land than over sea (figure 1.4). This is mainly because of the new ECOCLIMAP land surface roughness map used in HARM-CY43. The difference is below 0.5 m/s (sea) and below 1 m/s (land), which corresponds to 6% (0.5 m/s difference : 8 m/s average) and 25% (1 m/s difference : 4 m/s average). So, the difference at 10 m height is fairly large, especially onshore.

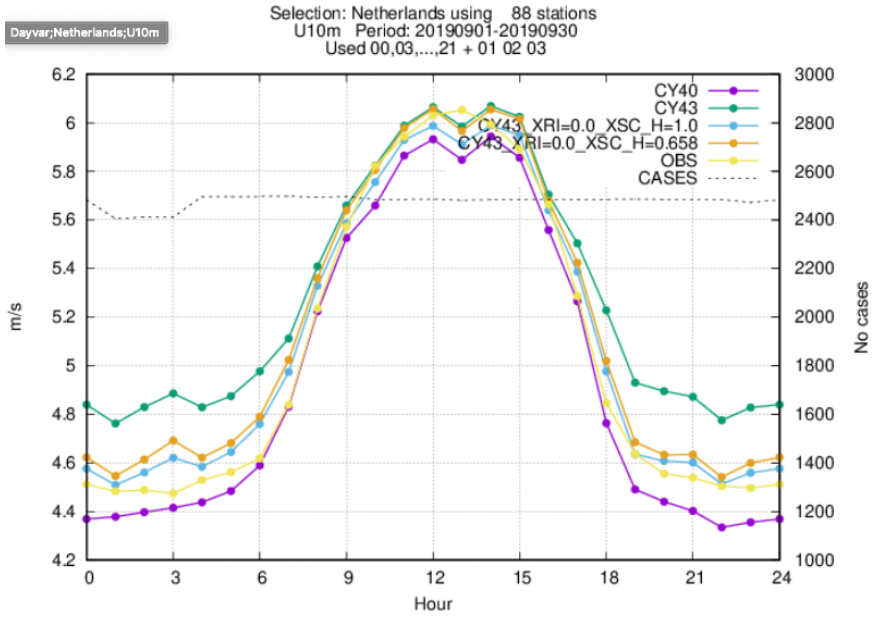


Figure 1.1: daily cycle of the wind speed for September 2019 averaged over 88 KNMI stations (onshore and offshore combined) in The Netherlands (yellow) compared to DOWA/HARM-CY40 (purple) and WINS50/HARM-CY43 (green). The blue and orange lines are HARM-CY43 runs with XRIMAX = 0 instead of 0.2 and a XSCALE_H_TREE of 0.658 (just like in WINS50/HARM-CY43; orange) and 1 (blue).

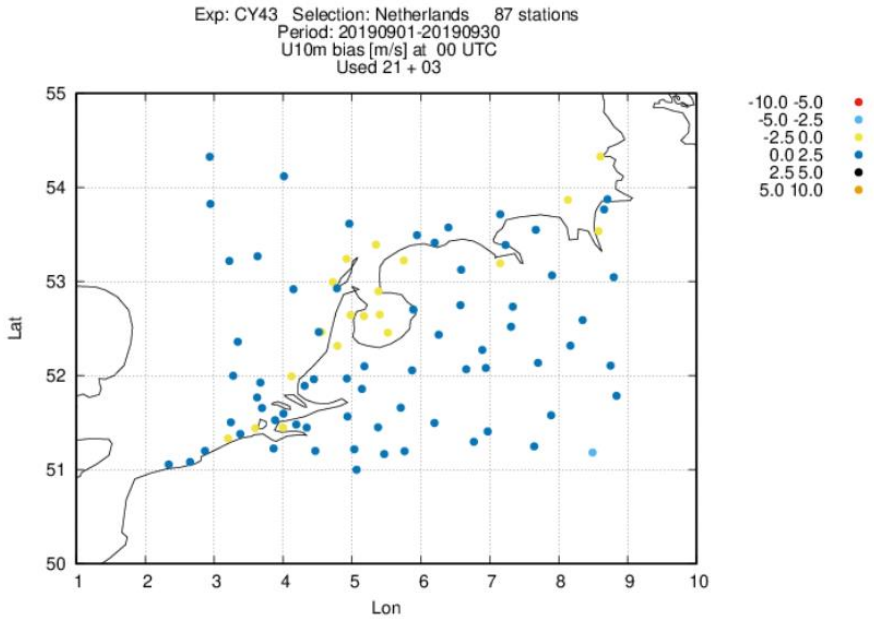


Figure 1.2: The average bias of the WINS50/HARM-CY43 wind speed at 00 UTC for 87 KNMI stations in The Netherlands for September 2019.

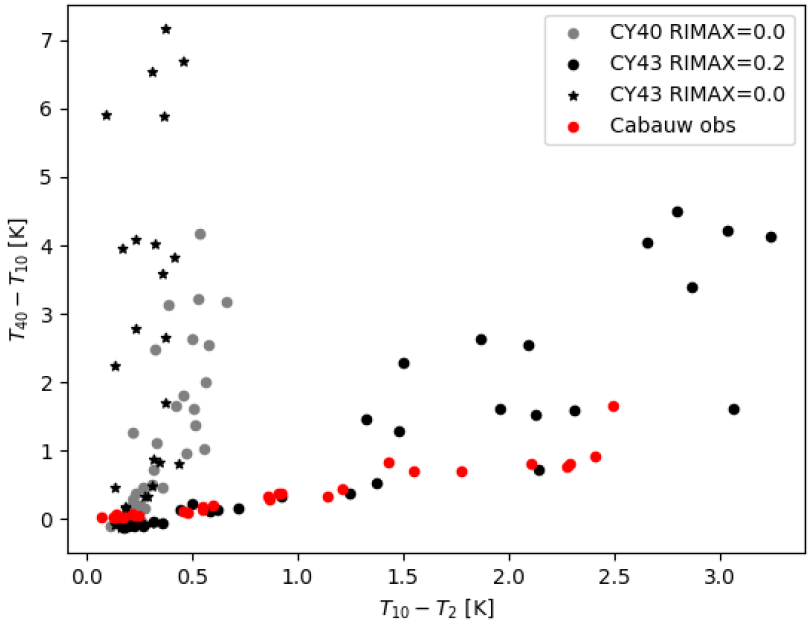


Figure 1.3: the averaged night-time (between 23:00 and 3:00 UTC) temperature gradient close to the surface (between 2 and 10 m height) compared to further away from the surface (between 10 and 40 m) from measurements at Cabauw (red dots), HARM-CY43 (black dots), the HIRLAM-default version of HARM-CY43 with XRIMAX set to 0.0 (black stars) and DOWA/HARM-CY40 (grey dots) for September 2019 at Cabauw.

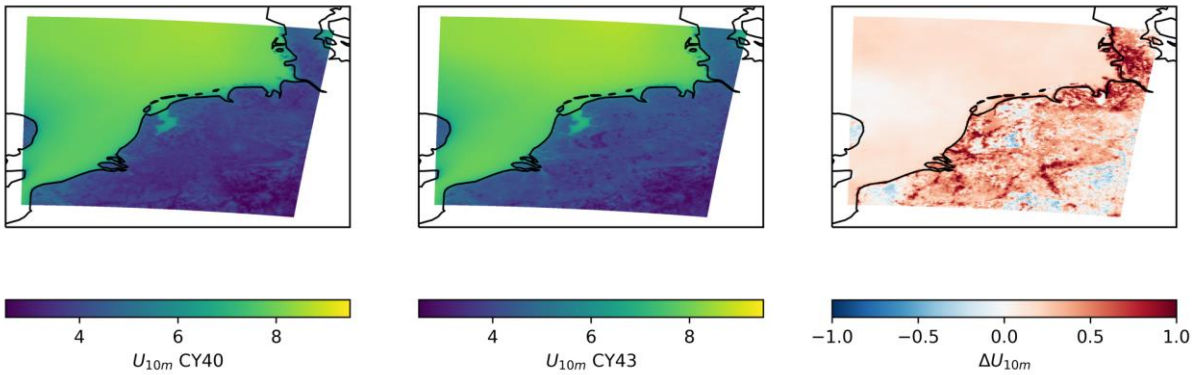


Figure 1.4: Mean wind speed in DOWA/HARM-CY40 (left), HARM-CY43 (middle), and the difference between HARM-CY40 (DOWA) and HARM-CY43 (WINS50) (right) at 10 m averaged over 9 months in 2019 (January up to and including September).

2.2 Comparing DOWA and WINS50 climatology at hub height

For the wind atlases we are mainly interested in the difference in wind speed at hub height. When comparing the wind measurements at 80 m height for the 9 months when HARM-CY40 (DOWA) and HARM-CY43 (WINS50) were both available (January up to and including September 2019) it becomes clear that the difference is still larger over land than over sea, but less than at 10 m height (compare figure 1.4 and figure 1.5). Again this is mainly because of the new ECOCLIMAP land surface information (and the different roughness length calculated with this new land surface information) used in HARM-CY43.The difference is below 0.2 m/s (sea) and below 0.5 m/s (land) so less than 2% (0.2 m/s difference : 10 m/s average) offshore and less than 7% onshore (0.5 m/s difference : 7 m/s).

- For the offshore measurements this is below the typically required measurement accuracy of 2% [Wijnant et al., 2019]. The difference will be even smaller at hub heights above 80m (that are more common for offshore turbines). An important conclusion to draw here is that - based on this 9 month comparison – the inhomogeneity between HARM-CY40 and HARM-CY43 is within measurement accuracy around hub height.
- For the onshore measurements it is not. The accuracy of wind measurements at the Cabauw mast is 1% (or 0.1 m/s at low wind speeds) measurements [Knoop et al., 2020]. However, the performance varies depending on the atmospheric conditions. For example, during daytime conditions wind speed profiles of HARM-CY43 are closer to the observations on average.

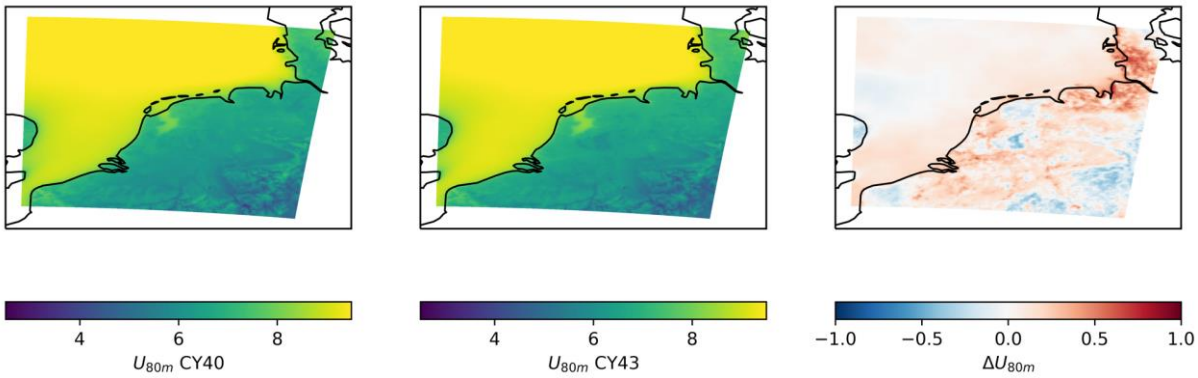


Figure 1.5: Mean difference between HARM-CY40 (DOWA) and HARM-CY43 (WINS50) at 80 m high averaged over 9 months in 2019 (January up to and including September).

At sea the difference HARM-CY40 (DOWA) and HARM-CY43 (WINS50) is largest for stable atmospheric situations (when the sea is cold compared to the air above). This occurs most often in the spring (figure 1.6-middle panel). In winter there are more stable conditions and larger differences between HARM-CY40 and HARM-CY43 on land (figure 1.6-left panel).

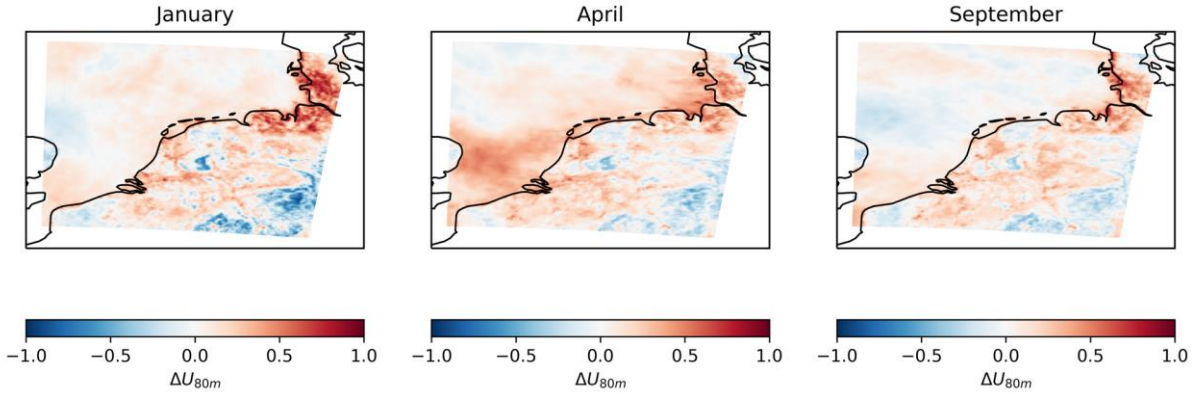


Figure 1.6: Mean difference between HARM-CY40 (DOWA) and HARM-CY43 (WINS50) at 80 m high for January 2019 (left), April 2019 (middle) and September 2019 (right)

3. Conclusion

The difference between HARM-CY40 (DOWA) and HARM-CY43 (WINS50) is fairly large at 10m height, especially onshore (difference below 25%; offshore below 6%). This is mainly because of the new ECOCLIMAP land surface roughness map used in HARM-CY43. At hub height the effect of the surface roughness is less and the differences between HARM-CY40 and HARM-CY43 are significantly lower. On land they are below 7% and offshore below the typically required measurement accuracy of 2%.

4. Literature

Faroux et al., 2013: Faroux, S., Kaptué Tchuenté, A. T., Roujean, J.-L., Masson, V., Martin,E., and Le Moigne, P.: ECOCLIMAP-II/Europe: a twofold database of ecosystems and surface parameters at 1 km resolution based on satellite information for use in land surface, meteorological and climate models, Geosci. Model Dev., 6, 563-582, doi:10.5194/gmd-6-563-2013, 2013.

http://www.geosci-model-dev.net/6/563/2013/gmd-6-563-2013.html

Hersbach et al., 2020: https://doi.org/10.1002/qj.3803 The ERA5 global reanalysis - Hersbach - 2020 - Quarterly Journal of the Royal Meteorological Society - Wiley Online Library

Knoop et al., 2020: Knoop, S.; Ramakrishnan, P.; Wijnant, I. Dutch Offshore Wind Atlas Validation against Cabauw Meteomast Wind Measurements. *Energies* **2020**, *13*, 6558. https://doi.org/10.3390/en13246558 (chapter 3 https://www.mdpi.com/1996-1073/13/24/6558)

Wijnant et al., 2019 (chapter 2.2): Wijnant, I.L., B. van Ulft, B. van Stratum, J. Barkmeijer, J. Onvlee, C. de Valk, S. Knoop, S. Kok, G.J. Marseille, H. Klein Baltink, A. Stepek. The Dutch Offshore Wind Atlas (DOWA): description of the dataset. KNMI Technical report TR-380 The+Dutch+Offshore+Wind+Atlas+(DOWA)_description+of+the+dataset (8).pdf

Appendix 1

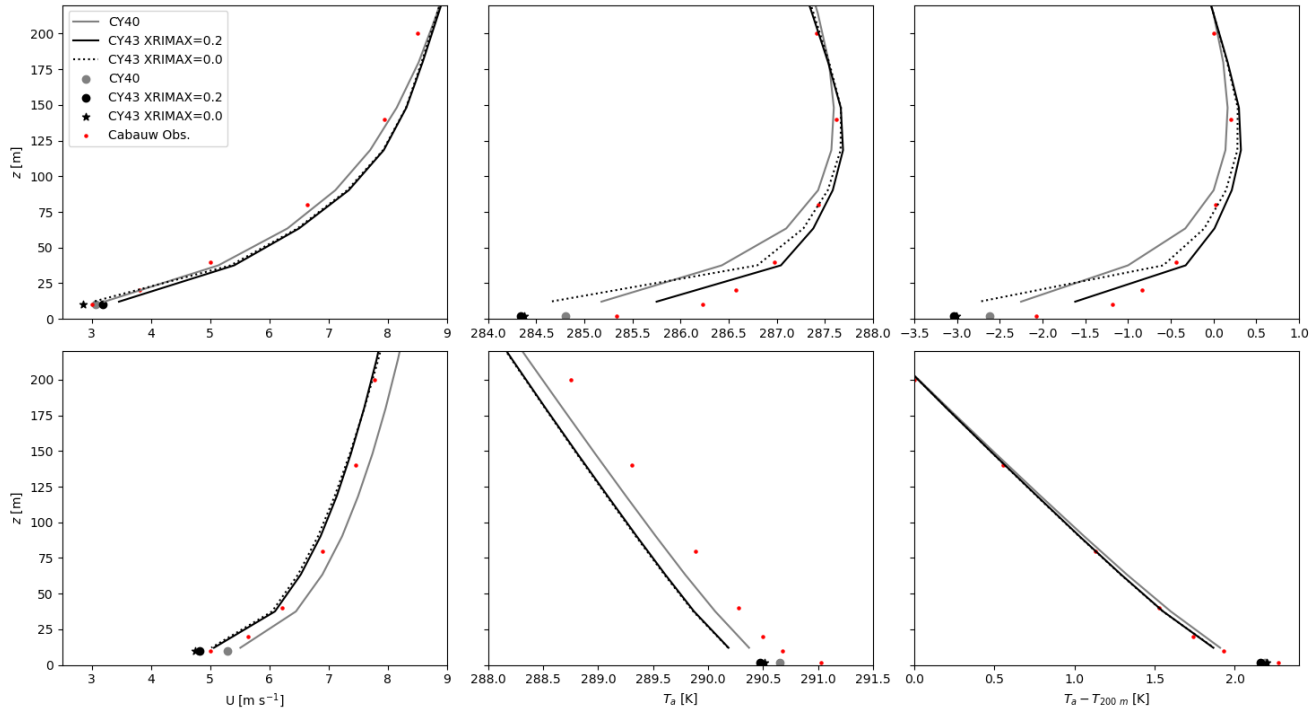
KNMI North Sea Wind (KNW) atlas	Dutch Offshore Wind Atlas (DOWA)	Extension DOWA (WINS50)
• 1979-2019 (40+ years)	• 2008-2018 (11 years)	• 2019-2021 (3 years)
• Captures the variability of the North Sea wind climate (40 years long enough)	• Does not capture the variability of the North Sea wind climate (11 years not long enough)	• Does not capture the variability of the North Sea wind climate (11+3 years not long enough)
• Using re-analysis ERA-Interim and mesoscale weather model HARMONIE Cycle 37h1.1	• Using re-analysis ERA5 (follow-up of ERA-Interim with higher spatial and temporal resolution) and mesoscale weather model HARMONIE-AROME[5] Cycle 40h1.2.tg2 (turbulence is better modelled) [6]	• Using re-analysis ERA5 and mesoscale weather model HARMONIE-AROME Cycle 43h2.1
• HARMONIE used as downscaling-tool only (data-assimilation of measurements in ERA-Interim only)	• Additional measurements assimilated in HARMONIE (ASCAT-satellite surface wind measurements and MODE-S-EHS aircraft wind profile measurements)	• Same additional measurements assimilated in HARMONIE (ASCAT-satellite surface wind measurements and MODE-S-EHS aircraft wind profile measurements) then for DOWA
• Climatological information up to and including a height of to 200 m	• Climatological information up to and including a height of 600m	• Climatological information up to and including a height of 600m
• Lacks the information required for further LES-downscaling	• Information required for further LES-downscaling included	• Information required for further LES-downscaling included
• Cold starts: limited quality of hourly correlation with measurements (e.g. diurnal cycle)	• No cold starts: better hourly correlation with measurements and representation of the diurnal cycle	• No cold starts
• Uniform wind shear correction applied	• No wind shear correction required	• No wind shear correction required

[5] https://journals.ametsoc.org/doi/10.1175/MWR-D-16-0417.1

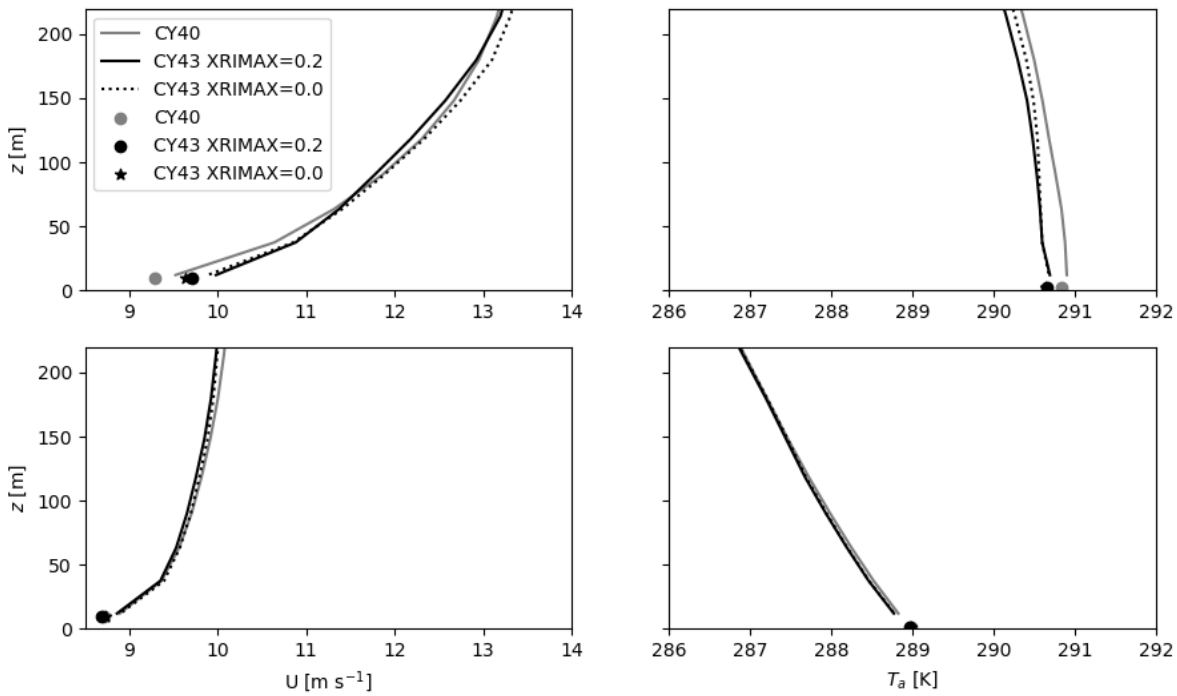
[6] The wind information provided by Harmonie not only improved because of the better physics, but also because the first guess (3 hour ahead forecast) used in the 3DVAR assimilation model improved. This meant that fewer measurements were rejected (more measurements assimilated). This also improves the analysis/forecast.

Appendix 2

Comparing the average wind and temperature profiles for September 2019 for one onshore and one offshore location, the average differences between the two versions of HARMONIE are between ~0.01 and 0.3 m s^{-1}. For temperatures close to the surface the differences are larger ~0.01—1.2 K. However, the differences in wind speed between the versions are only minor at the offshore location for both stable and unstable conditions.



Wind (left), temperature (middle) and scaled temperature (right) profiles for September 2019 at Cabauw (land). Upper panels night (23-3 UTC) and lower panels day (11-15 UTC). Measurements from the Cabauw tower (red dots), HARM-CY40 (grey), HARM-CY43 (black, solid), and HARM-CY43 with XRIMAX = 0.0 (black, dotted). The dots and stars of the simulations indicate the 10-m wind speed and the 2-m temperature diagnostics.



Wind (left), and temperature (right) profiles for September 2019 at FINO1 (sea). Above sensible heat flux < 0 (n=32) and below > 0 (n=688), HARM-CY40 (grey), HARM-CY43 (black, solid), and HARM-CY43 with XRIMAX = 0.0 (black, dotted). The dots and stars of the simulations indicate the 10-m wind speed and the 2-m temperature diagnostics.