Assimilation of Aeolus HLOS product in a regional scale NWP

Stephen Tjemkes, Hans Bonekamp, Joerg Steinwagner and Gerard Hesselmans

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Summary

- **Assimilation of Aeolus HLOS and Transformed Retrievals (TR) either alone or in combination affects the regional scale analysis of atmospheric state by the WRF-4DEnVar system. Already a small number of HLOS products have a noticeable impact.**
- **The impact on deterministic forecast appears to be neutral.**
- **Possible reasons**
  - **Too short of an experimental time period**
    - **1.5 day (a 7 day experiment is ongoing)**
  - **Only one meteorological situation**
    - **North Atlantic low pressure system**
    - **Next we consider a summer convective or Medicane situation(s)**
  - **Too few independent observations as reference**
    - **No statistical representative set**
  - **Settings of the 4DEnVar**
    - **6-hour data assimilation window 1 hour sampling**
    - **6-hour window with 10 min sampling should improve temporal collocation of model and observations (would then add CrIS/HIRAS-2 to IASI TR)**

2.0 General overview

Background

- There is a need to provide short range weather forecast (between 1-24 hours) to estimate the renewable energy production by solar and wind power plants.
- This requires the use of NWP models which have high spatial and temporal resolution. Large scale global models are not able to resolve the spatial/temporal requirements by these applications. Especially when the atmospheric state is rapidly changing on short time, and spatial scales (orography).
- The analysis of middle atmospheric dynamics by regional scale NWP especially over data void regions could benefit from satellite observations in particular:
  - HLOS winds from Aeolus mission
  - High frequent observations of T/q by the constellation of hyperspectral IR instruments (IASI, CrIS, HIRAS, AIRS)
- Assimilation of HLOS is considered less suitable for regional scale applications (mainly coverage)
- Assimilation of IASI L1-observations is less optimal as it not explores full information content.

Objective:

Analyse value added

1. **of Aeolus HLOS and**
2. **of so-called Transformed Retrievals derived from IASI observations**

in the analysis prepared by WRF-4DEnVar.

Demonstrated using traditional Data Denial Experiments:

- **CTRL: conventional surface observations + HLOS + TR**
- **NOHL: conventional surface observations + TR**
- **NOTR: conventional surface observations + HLOS**
- **NHTR: conventional surface observations**

Assimilation system 4DEnVar and Data

- **4DEnVar 4D Var method, uses flow dependent background error [derived from 20 Member Ensemble (2 physical packaged, 10 stochastic perturbations SKEB and SPPT)]**
- **Data consists of**

1. **Transformed Retrievals:**
   - **are regular L2 products, projected into feature space to remove background used for the retrieval. It has been shown (theory and real data with global system) that they produce identical increments as L1 assimilation (Migliorini 2012, Salonen et al. 2017)**

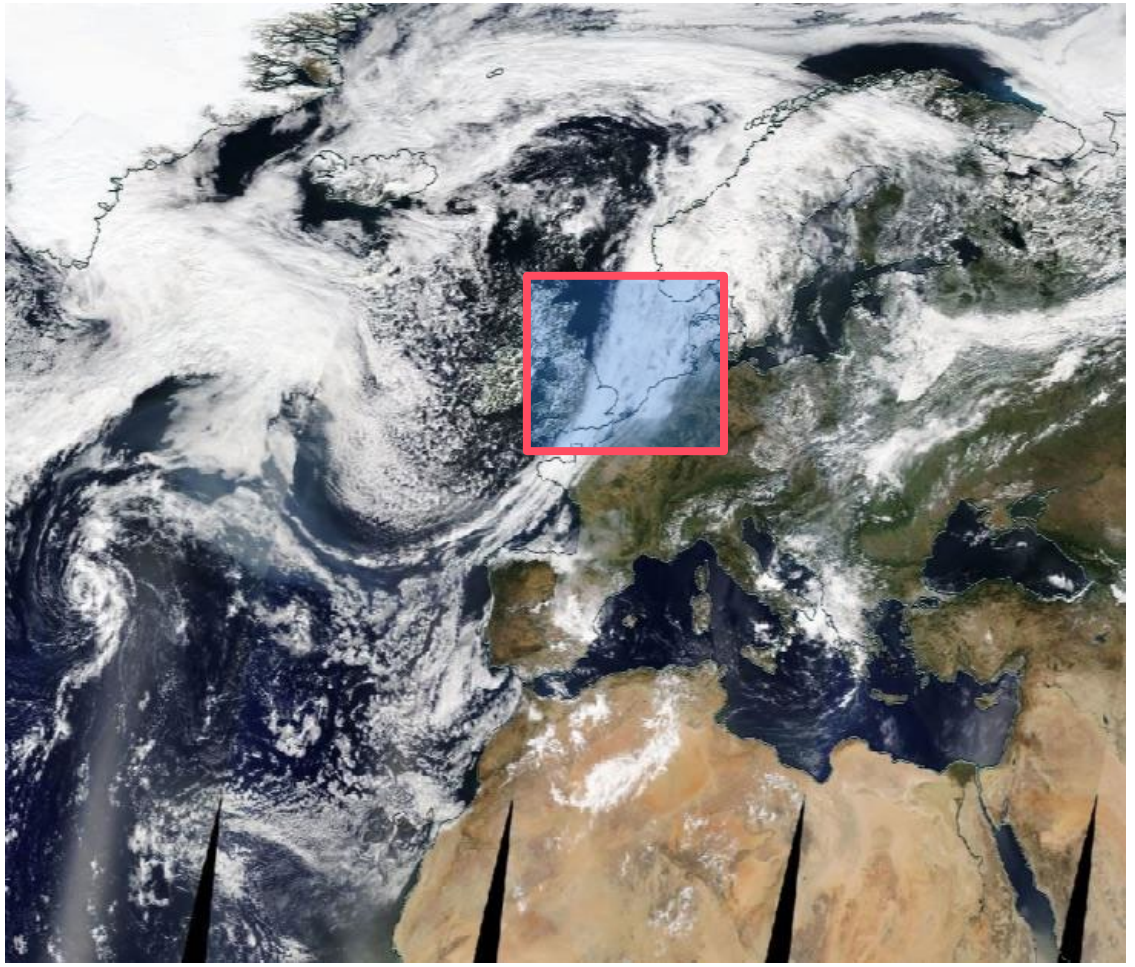
$$\hat{\mathbf{x}}' = \hat{\mathbf{\Lambda}}^T \left(\hat{\mathbf{\Lambda}}\hat{\mathbf{\Lambda}}^T + \mathbf{I}\right)^{-1} \hat{\mathbf{\Lambda}}\mathbf{x} + \left(\hat{\mathbf{\Lambda}}\hat{\mathbf{\Lambda}}^T + \mathbf{I}\right)^{-1} \mathbf{x}'_a + \hat{\mathbf{\Lambda}}^T \left(\hat{\mathbf{\Lambda}}\hat{\mathbf{\Lambda}}^T + \mathbf{I}\right)^{-1} \epsilon'$$

2. **Rayleigh winds as per L2b (from vre)**

Where are we?

Our test region

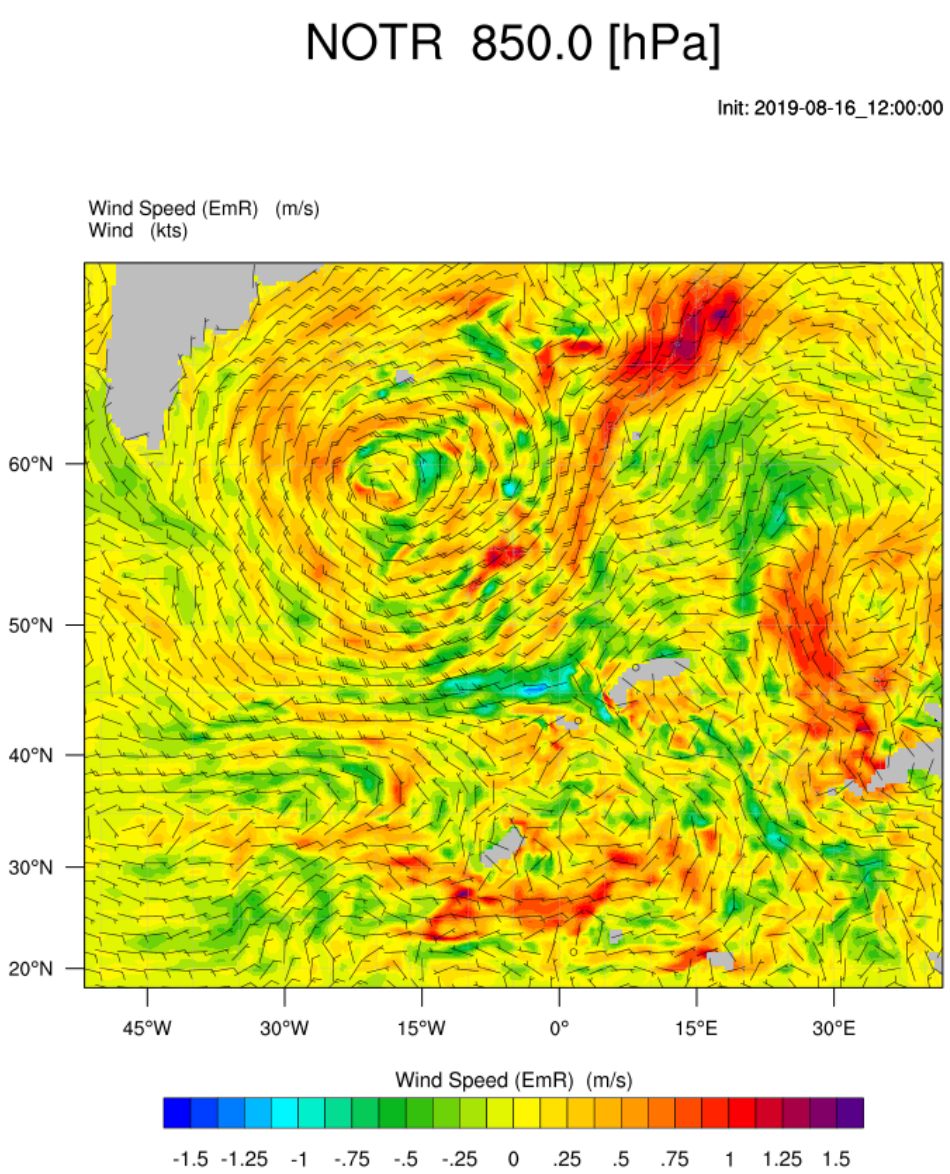
- We chose a region centered at 50N, 5W
  - The extension North - South is about 4400 km
  - The extension West – East is about 5200 km
  - The grid cell size is 27 km,
- The region is much larger than the particular area of interest (North Sea and surroundings) to mitigate potential effects from lateral boundary conditions



3.4 First Experimental results

Windspeed: 20190816:1200

- NOTR – NHTR
  - Only a few Aeolus HLOS with DA-window

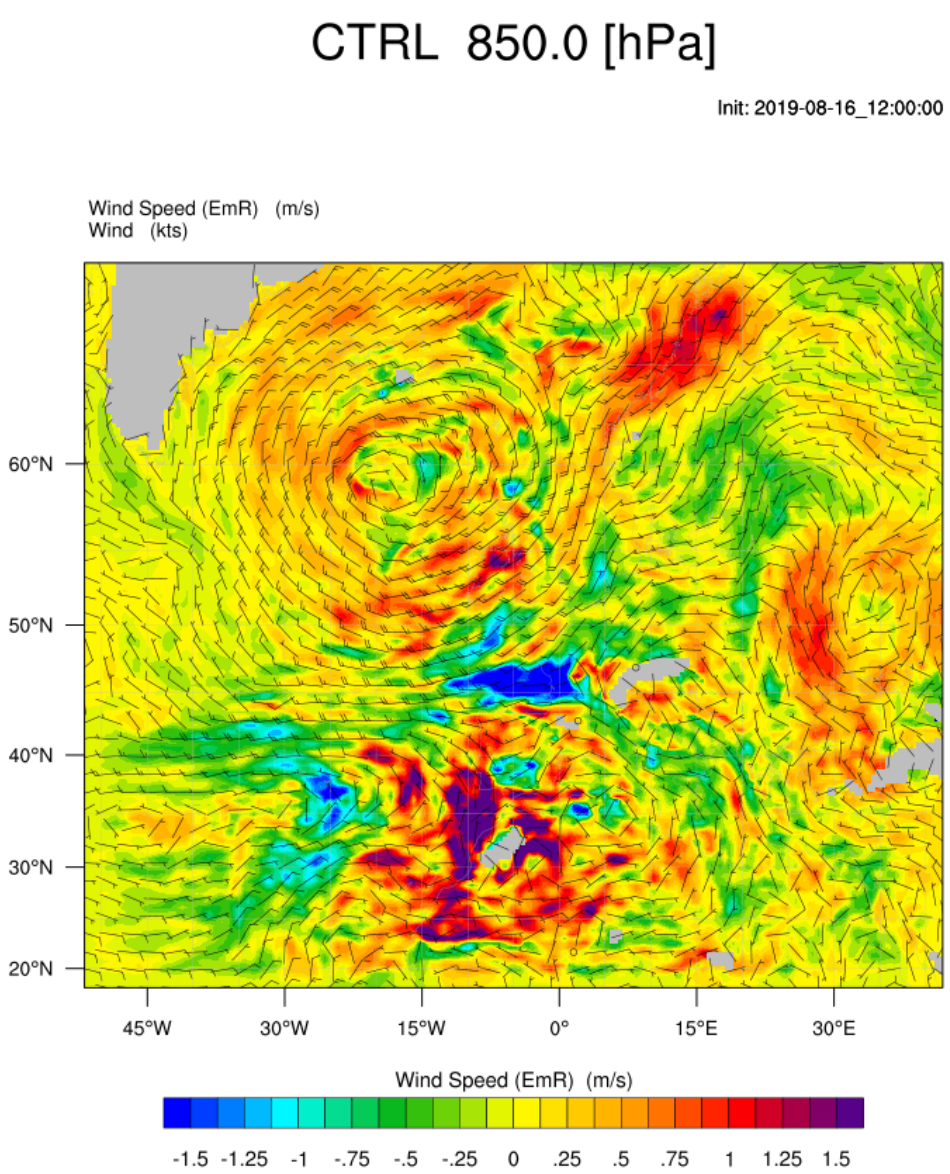


OUTPUT FROM WRFDA V4.3.3
WE = 195 ; SN = 165 ; Levels = 45 ; Dis = 27km ; Phys Opt = 8 ; PBL Opt = 2 ; Cu Opt = 6

Verisk

Windspeed: 20190816:1200

- CTRL – NHTR
  - IASI TR add information in the lower half were most of the TR are located.

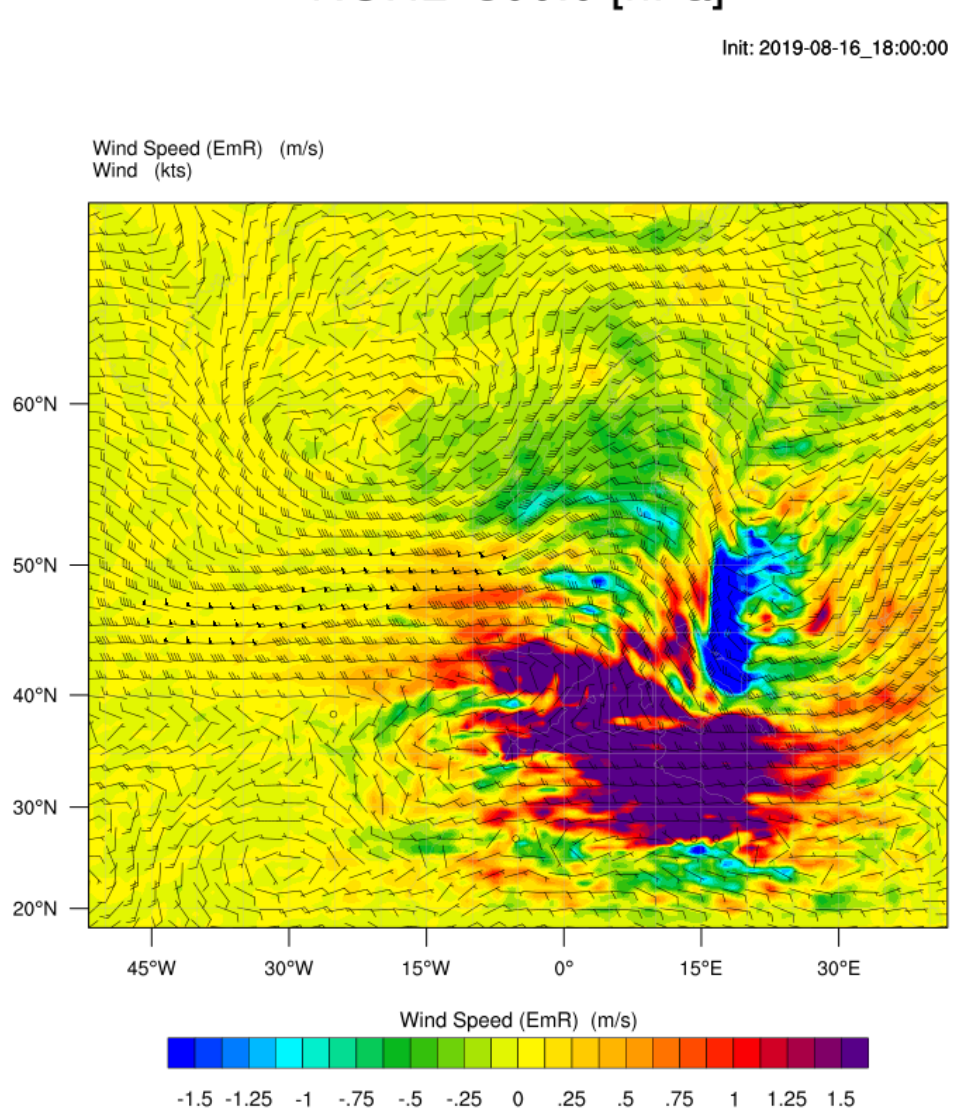


OUTPUT FROM WRFDA V4.3.3
WE = 195 ; SN = 165 ; Levels = 45 ; Dis = 27km ; Phys Opt = 8 ; PBL Opt = 2 ; Cu Opt = 6

Verisk

Windspeed: 20190816:1800

- NOHL – NHTR
  - IASI TR add information in the lower half were most of the TR are located.

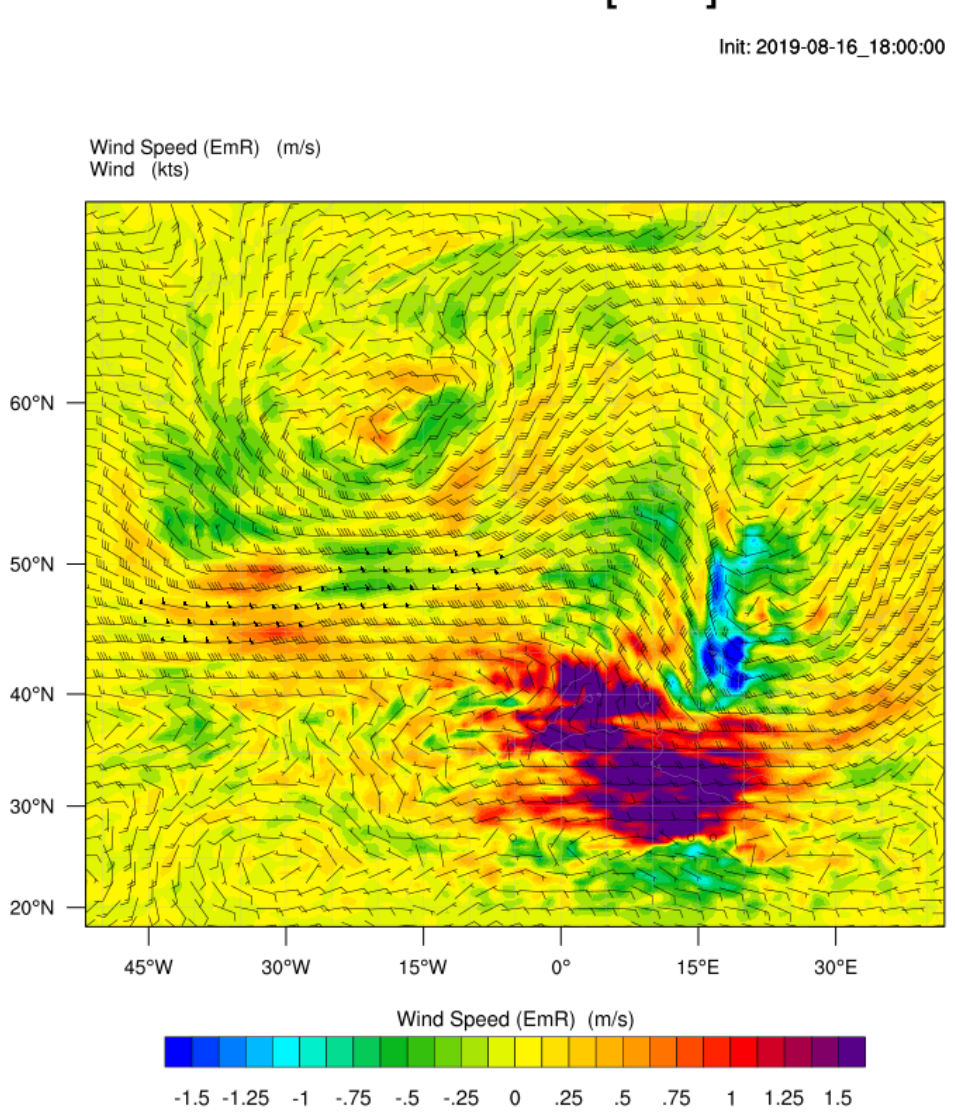


OUTPUT FROM WRFDA V4.3.3
WE = 195 ; SN = 165 ; Levels = 45 ; Dis = 27km ; Phys Opt = 8 ; PBL Opt = 2 ; Cu Opt = 6

Verisk™

Windspeed: 20190816:1800

- CTRL – NHTR
  - HLOS not only adds information in upper half, but seems to moderate impact of the TR.



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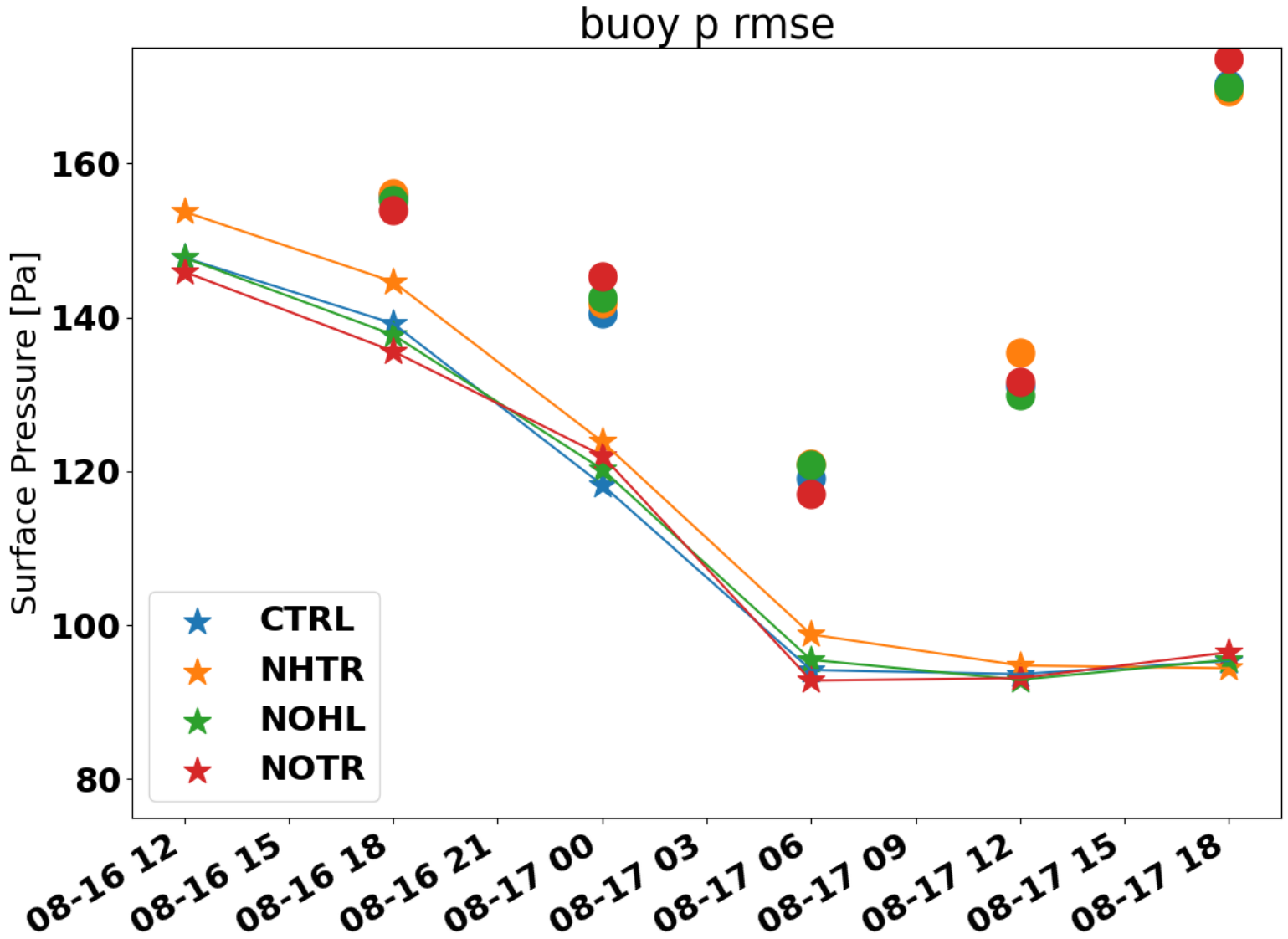
Verisk™

Some statistics

- OmB & OmA for HLOS
  - Bias -0.25 – 0.5 m/s
  - RMSE 8-9.6 (OmB) and OmA is reduced by 1%
- Averaged domain number



3.0 Validation of deterministic forecast

Deterministic forecast

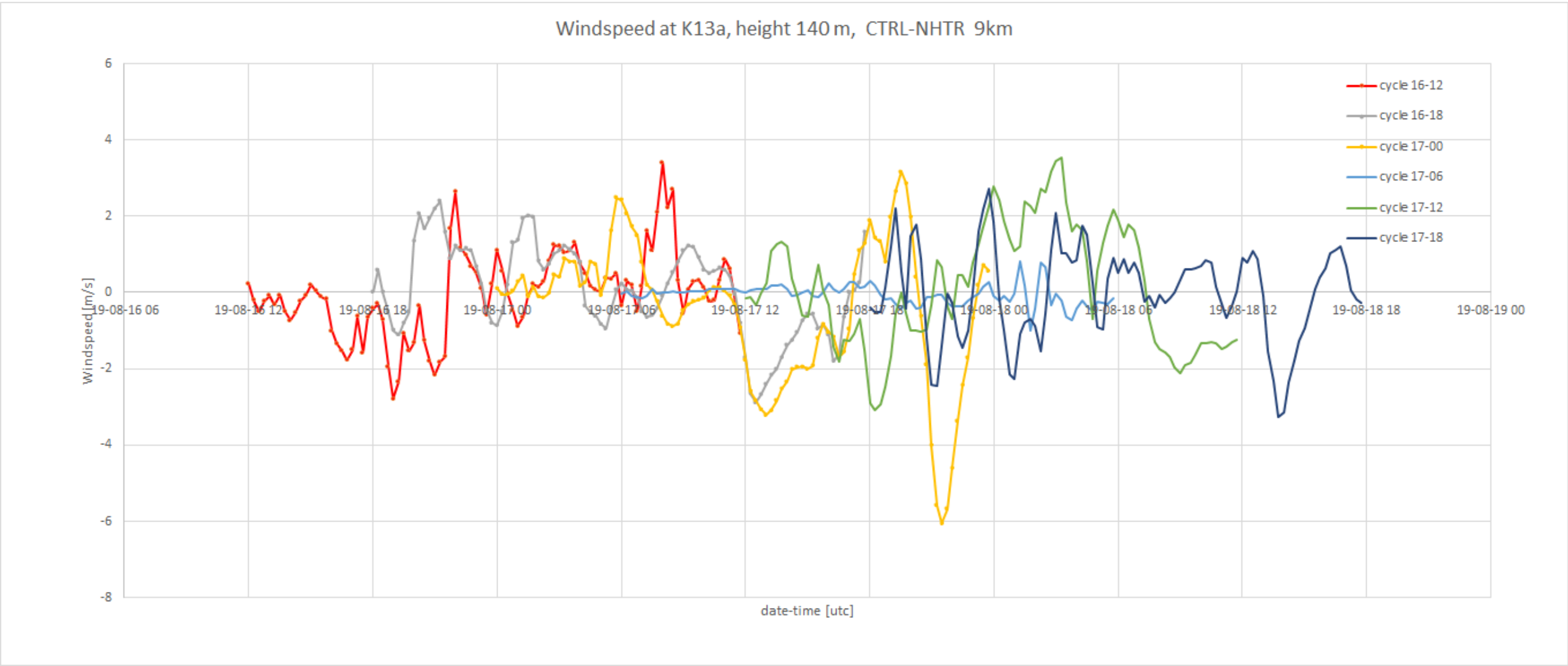
Prepared deterministic short term forecast (24 h), concentrated on windspeed forecast at 140 m representative for modern hub-height of wind turbines.

Compared to independent observations at 140 at site in the North Sea and Cabauw.

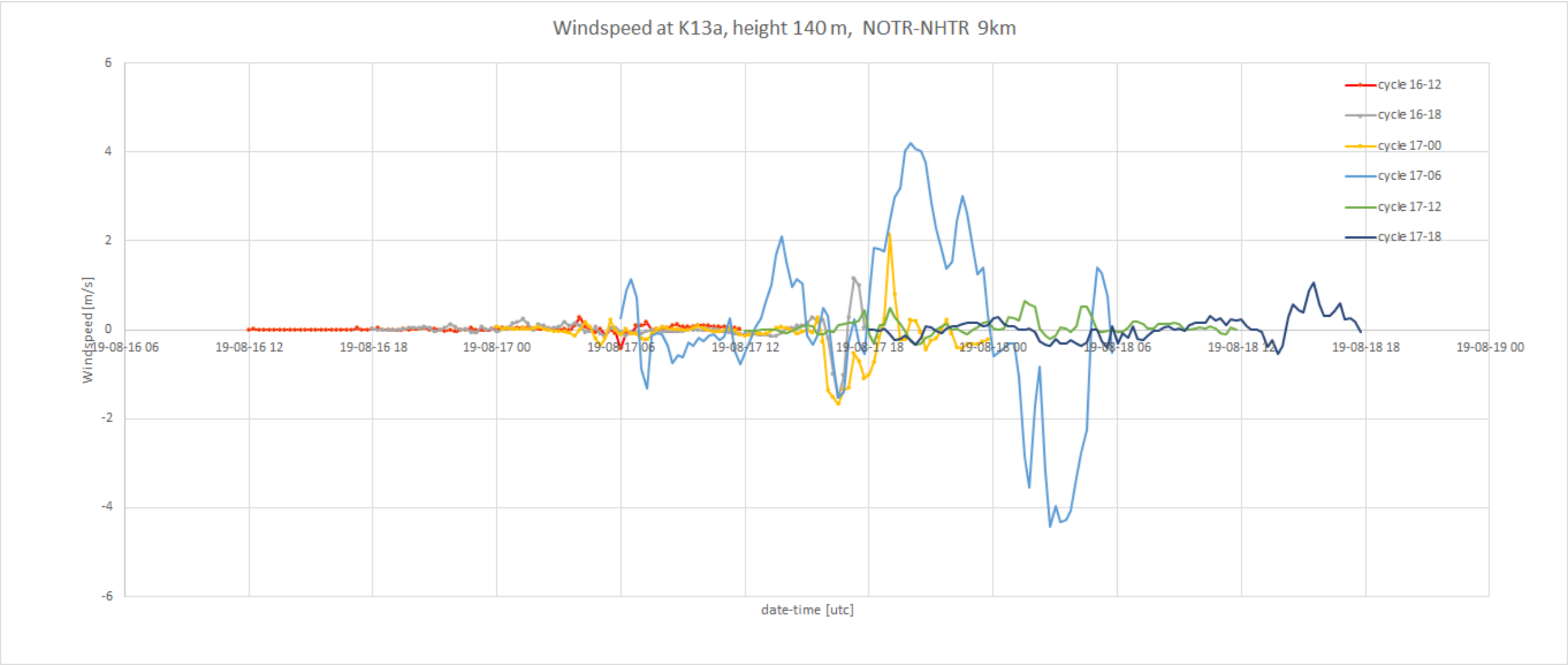
- No conclusive results all experiments have very similar statistics.
- bias 0 - -0.5 m/s depending on forecast period, rms 1 – 2 m/s also on forecast period.
- bias and rms decreases towards the end of forecast period.

Noted that the experimental period is very short and the number of reference sites is small hence these results are inconclusive.

Difference in deterministic short term (24h) forecast (CTRL-NHTR)



Difference in deterministic short term (24h) forecast (NOTR-NHTR)



3.1 Discussion

Discussion

- Ongoing experiment considers 7 days => lead to better statistics.
  - More independent reference data (Mode-S?)
- Current situation is dominated by large scale dynamics,
  - Would like to consider a situation where state is dominated by local processes (e.g. thunder storms, or Medicanes)
- With respect to calculating difference between model and observations 4DEnvar is closer to FGAT-method than 4DVar. To improve time collocation should move to finer time mesh of the ensemble data:1 hour => 10 min, which especially for dynamical situations, could be important
  - Will require more hyperspectral data to fill gaps (e.g. CrIS, HIRAS,)
- Scale analysis (not shown) indicates that especially the TR increases the energy in upper atmosphere of the analysis, at the higher wavenumber domain, unclear why.

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Thank you for your attention

Note Poster #2

https://wind-for-renewable-energy.aer.com