The Contribution of Aeolus Wind Observations to Global Sea Surface Wind Forecasts

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Aeolus Satellite

Introduction

In August 2018, the European Space Agency (ESA) launched the Aeolus satellite equipped with a Direct Detection Doppler Wind Lidar to characterise global wind profiles and improve numerical weather prediction (NWP) [1].

Detection principles

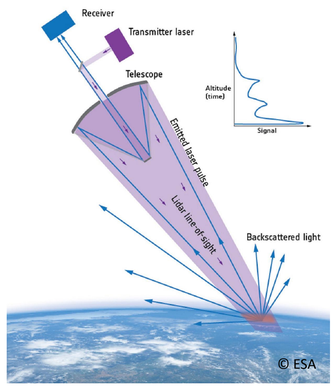
- Based on Doppler shift of backscattered laser light:

$$\Delta f = -\frac{2v_r}{\lambda_0}$$

- Two detection channels:
  Rayleigh channel - backscattering from air molecules;
  Mie channel - backscattering from large particles.

Wind products

- Rayleigh-clear and Mie-cloudy winds
- From surface to about 30 km in height
- 24 range bins with a vertical resolution of 250 m - 2 km
- Almost east-west horizontal wind component
- 2nd reprocessed dataset random error [2]
  Rayleigh-clear: 5-7 m/s
  Mie-cloudy: ~3.5 m/s



Study purpose

To evaluate the value of Aeolus observations to NWP, the observing system experiments (OSEs) with and without Aeolus data assimilation were performed by many meteorological institutes, such as the European Centre for Medium-Range Weather Forecasts (ECMWF), Météo-France, National Oceanic and Atmospheric Administration, etc. The tropical and polar upper troposphere and lower stratosphere are the regions where Aeolus has the most favourable effects on wind predictions [2-4]. However, much of the research done so far has not treated sea surface wind forecasts in much detail.

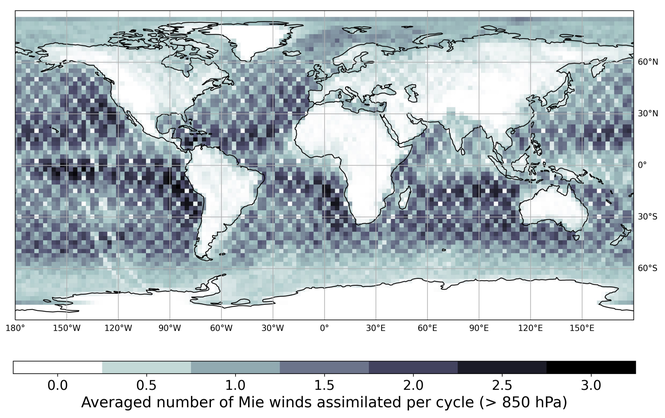
Given this, the main purpose of this study is to assess the impact of Aeolus wind assimilation on sea surface wind forecasts geographically by comparing with Advanced Scatterometer (ASCAT) winds.

Observing System Experiment

OSE settings [2]

- Model version: ECMWF cy47r2
- Resolution: outer loop resolution $T_{co}639$, ~18 km grid
- Forecast range: 240 h
- Data assimilation technique: 4D-Var, 12-hour assimilation window

Control experiment	Experiment with Aeolus	
Satellite and conventional observations	Satellite and conventional observations	**FM-B 2nd reprocessed dataset:** < 850 hPa: Rayleigh-clear + Mie-cloudy winds ≥ 850 hPa: Mie-cloudy winds



Data and Methods

ECMWF OSEs [5]

- First-guess departure of u and v components at 10 m height based on ASCAT winds from observation feedback dataset;
- Forecasts of u and v components at 10 m height with time interval of 24 h.

ASCAT Level-2 25 km sea surface winds [6]

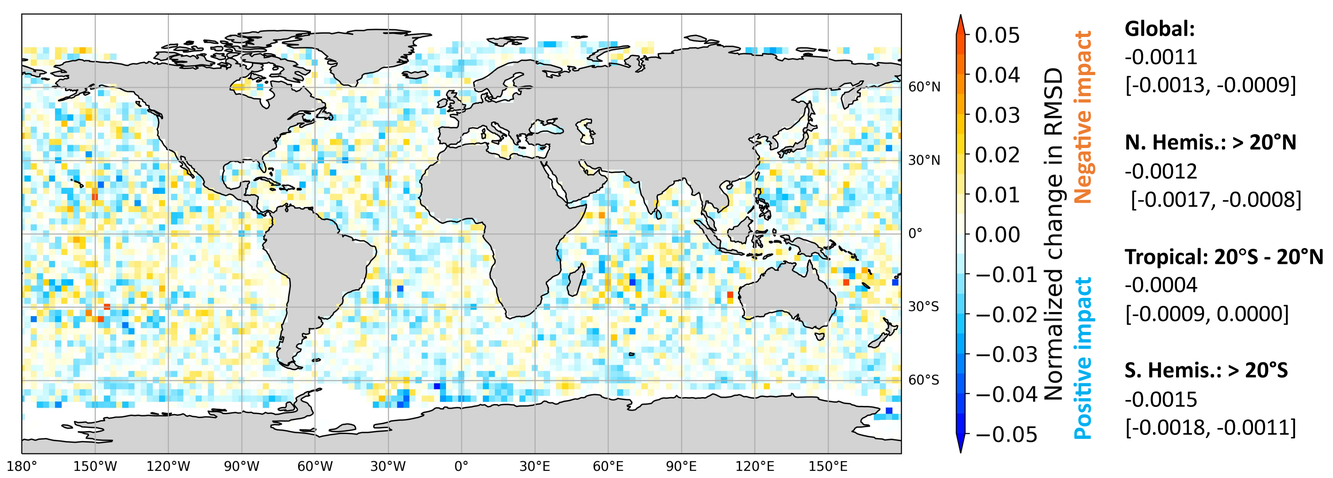
Normalized change in root-mean-square difference (NCRMSD) for wind vector.

$$NCRMSD = \frac{RMSD_{with\ Aeolus} - RMSD_{no\ Aeolus}}{RMSD_{no\ Aeolus}}$$

Study period: July 2019 – June 2020

Main Research Findings

1. Results for shortest-range wind forecasts based on first-guess departure



Global:
-0.0011
[-0.0013, -0.0009]

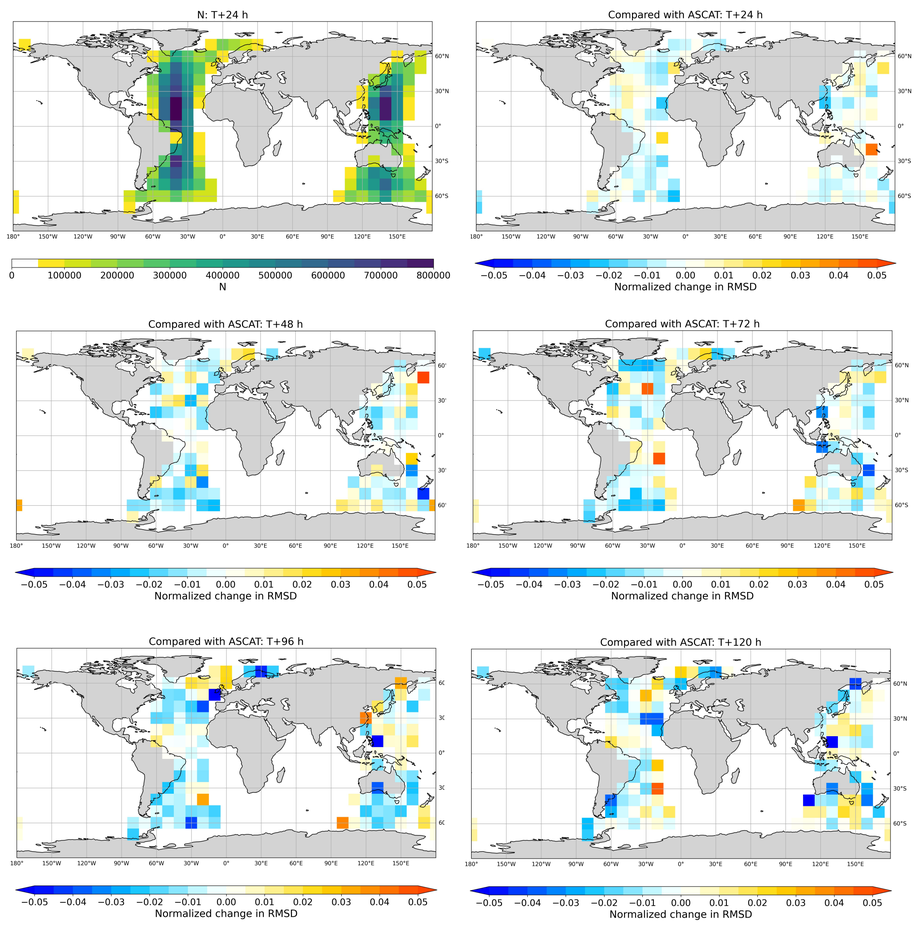
N. Hemis.: > 20°N
-0.0012
[-0.0017, -0.0008]

Tropical: 20°S - 20°N
-0.0004
[-0.0009, 0.0000]

S. Hemis.: > 20°S
-0.0015
[-0.0018, -0.0011]

- Below 850 hPa, Mie-cloudy winds assimilated into the model are mainly over the ocean regions between 60°S and 60°N except for the Intertropical Convergence Zone;
- For shortest-range forecasts, the overall impact of Aeolus on sea surface wind forecasts is positive for global oceans;
- For tropical oceans, the overall impact of Aeolus is nearly neutral;
- With forecast range extending, the positive impact of Aeolus becomes more evident, especially for the mid-latitude ocean regions in the Southern Hemisphere until T+96 h forecast step, which is comparable with the study by Rennie and Isaksen [2];
- The results give us information about which ocean regions benefit more from Aeolus wind observations; it also guides us to further investigate and in turn to avoid the detrimental impact cases.

2. Results for T+24 h to T+120 h wind forecasts



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