Royal Netherlands
Meteorological Institute
*Ministry of Infrastructure*
*and Water Management*


# A new high-resolution ocean wind forcing product for the Copernicus Marine Service

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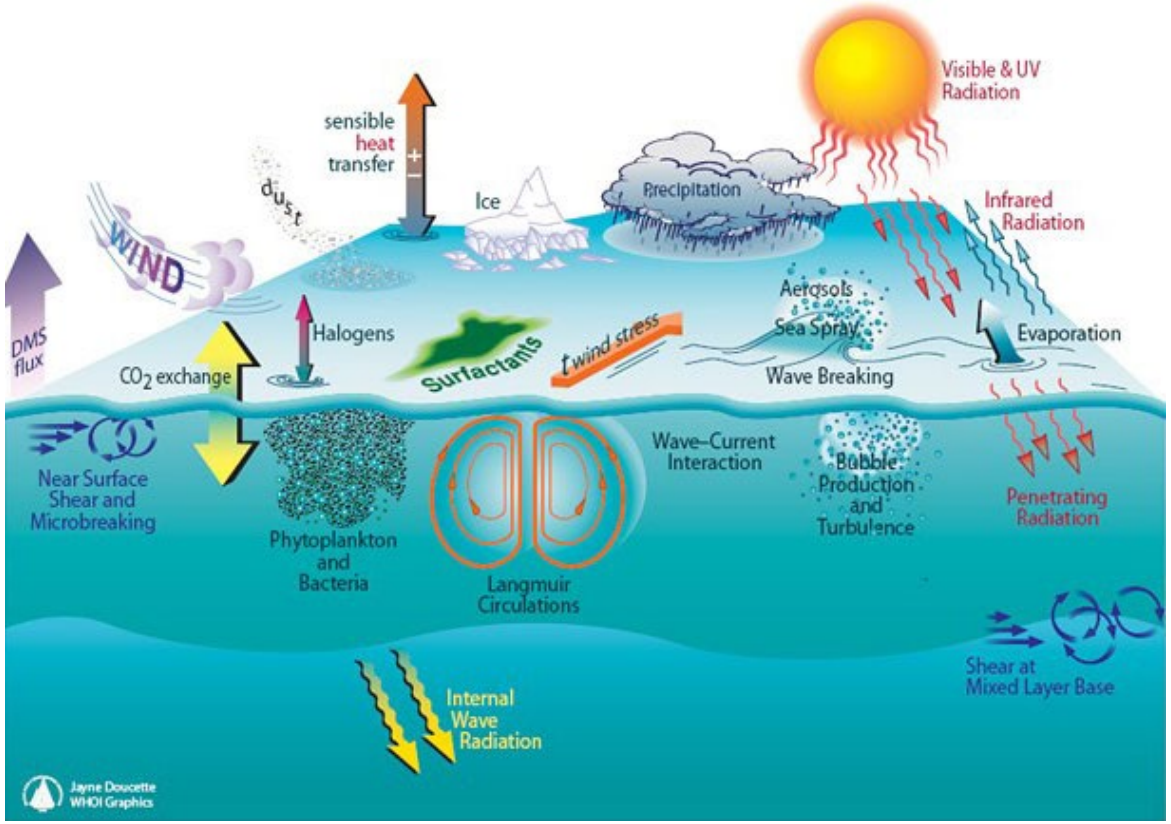
# Context

Many processes at the marine boundary layer are dependent on the surface wind:

- Ocean circulation
- Wave generation and storm surges
- Coastal sediment transport
- Momentum, heat and mass exchange

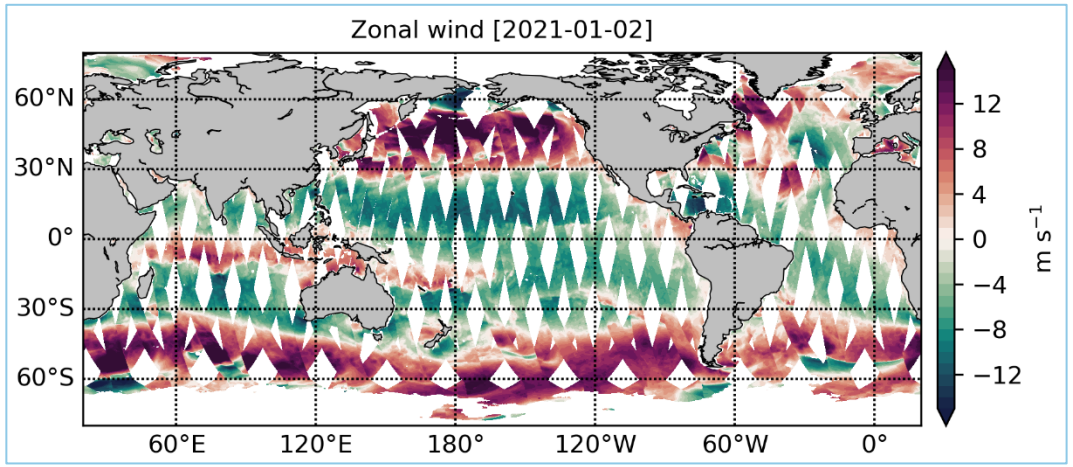
To accurately represent these processes in physical ocean models, global fields with high spatial and temporal resolution are needed



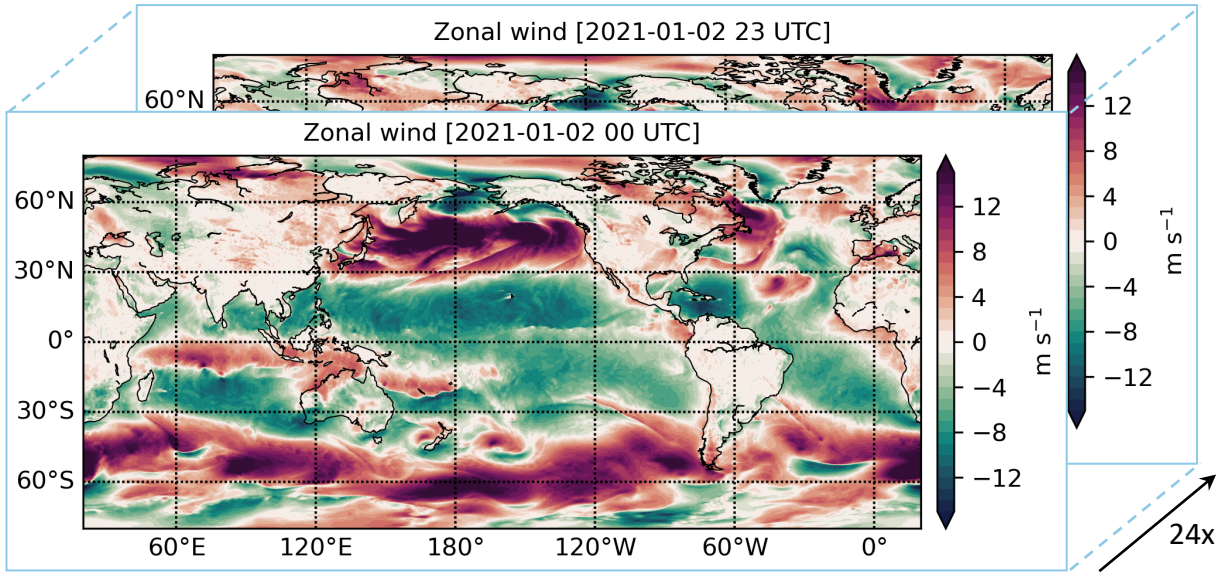

Source: Woods Hole Oceanographic Institution

# Wind field spatial and temporal coverage

- Remotely sensed surface winds have limited spatial and temporal coverage
- Numerical weather prediction (NWP) models provide global coverage at an hourly frequency
- Ocean models are generally forced with NWP model winds
- However, NWP model winds are not perfect…




Scatterometer daily coverage (Metop-B ASCAT)

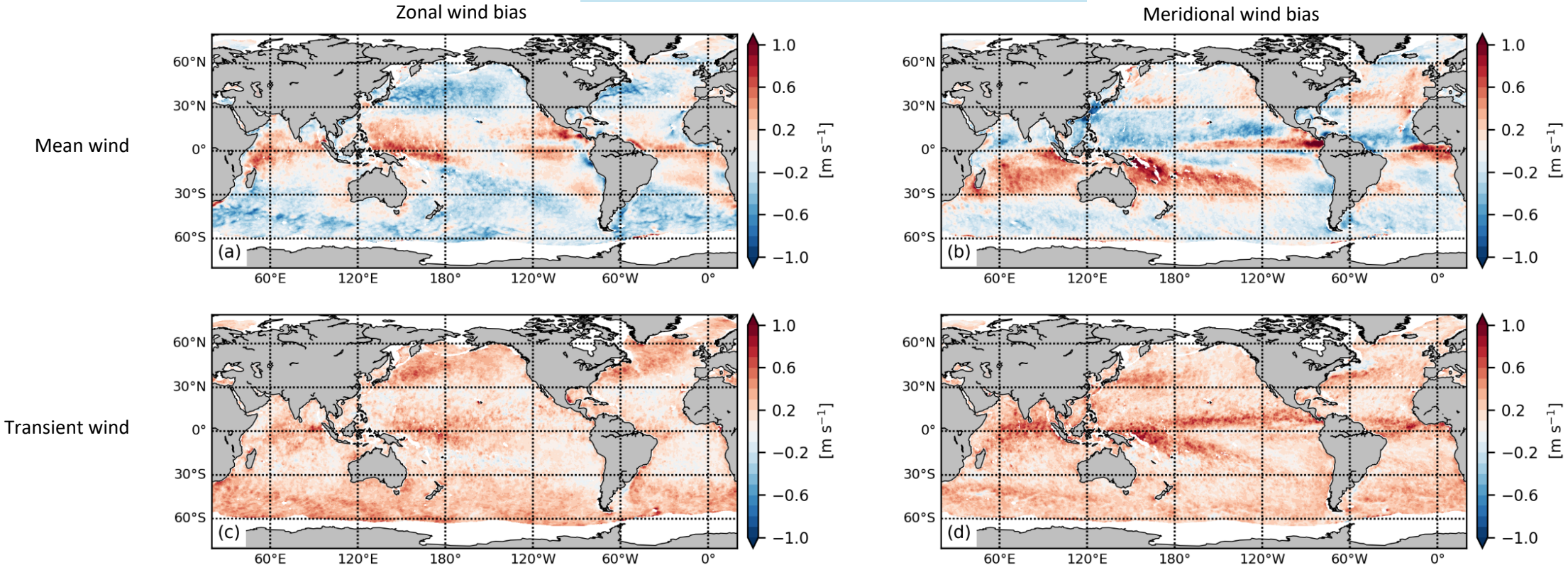



NWP model daily coverage (ECMWF ERA5)

# Numerical weather prediction model biases

- Persistent biases between scatterometer observations and ECMWF NWP model winds
- Lack of small-scale variability in ECMWF model winds

Metop-A ASCAT – ECMWF ERA5 [2019]




Belmonte Rivas, M. and A. Stoffelen (2019): *Characterizing ERA-Interim and ERA5 surface wind biases using ASCAT*, Ocean Sci., 15, 831–852, doi: 10.5194/os-15-831-2019.

# Scatterometer correction

- Use temporally-averaged differences between scatterometer observations and collocated NWP model winds to correct for persistent local NWP wind vector biases

$$SC(i,j,t_f) = \frac{1}{M}\sum_{t=1}^{M} u_{10s}^{scat}(i,j,t) - u_{10s}^{NWP}(i,j,t)$$

| | |
|---|---|
| *SC* | Scatterometer-based correction |
| *(i,j)* | Grid point spatial coordinates |
| $t_f$ | NWP model forecast time |
| *M* | Number of scatterometer observations at *(i,j)* in time window of *N* days |
| *t* | Observation time |
| $u_{10s}^{scat}$ | Stress-equivalent wind variable from scatterometer |
| $u_{10s}^{NWP}$ | Stress-equivalent wind variable from NWP model interpolated to *(i,j,t)* |

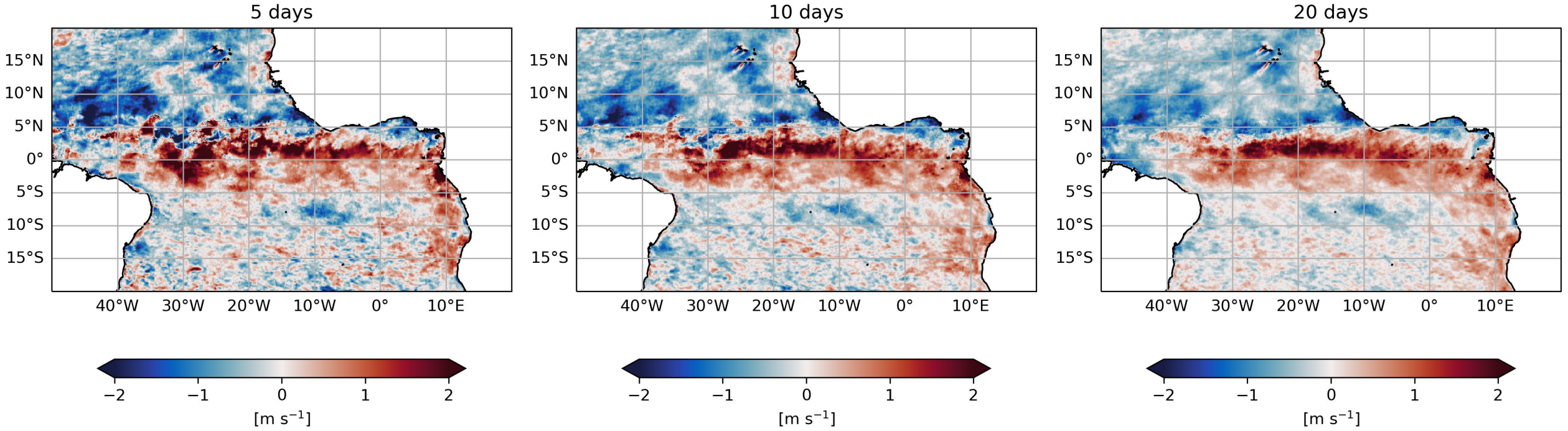
Trindade, A., M. Portabella, A. Stoffelen, W. Lin and A. Verhoef (2020), *ERAstar: A High-Resolution Ocean Forcing Product*, IEEE Trans. Geosci. Remote Sens., 1-11, doi: 10.1109/TGRS.2019.2946019.

# Scatterometer correction: window length

- Bias magnitude and spatial variability reduces for longer window lengths
- Persistent scatterometer-model biases remain

| | |
|---|---|
| Date | 20 January 2021 0 UTC |
| ECMWF model | ERA5 reanalysis |
| Scatterometers | Metop-B ASCAT<br>Metop-C ASCAT |

Meridional wind bias



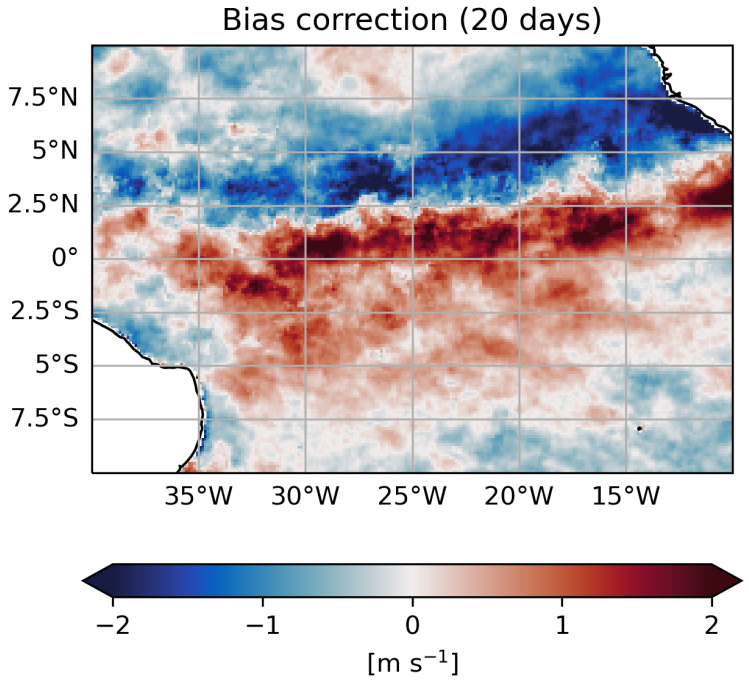
# Corrected ECMWF model wind fields

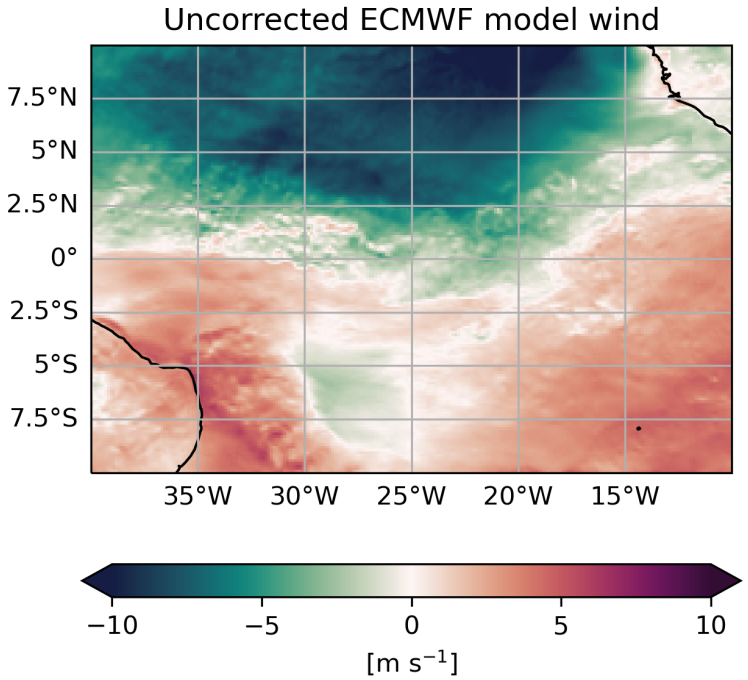
$$u_{10s}^{NWP*}(i,j,t_f) = u_{10s}^{NWP}(i,j,t_f) + SC(i,j,t_f)$$

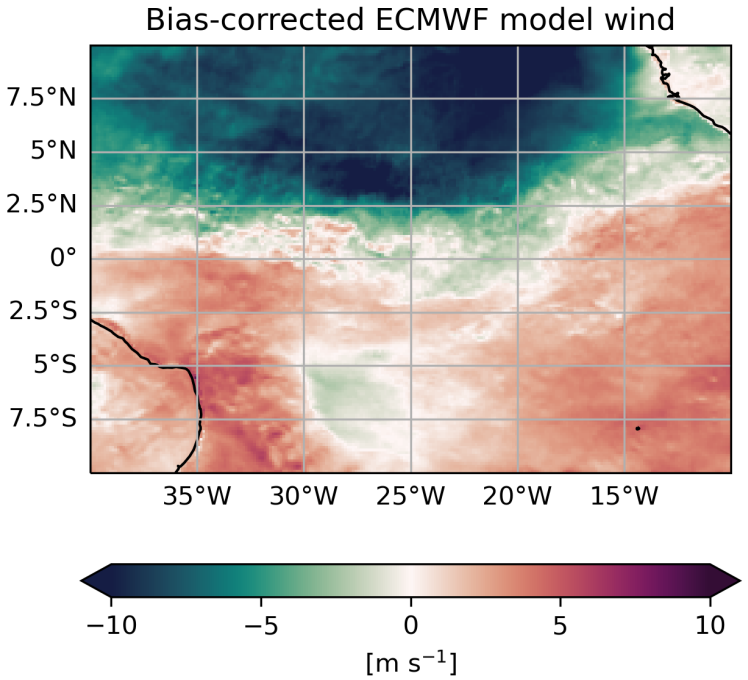
- 20-day average scatterometer-model differences larger than ± 2 m/s
- Enhanced local and regional wind gradients in the tropical Atlantic

| | |
|---|---|
| Date | 1 March 2022 12 UTC |
| ECMWF model | ECMWF operational |
| Scatterometers | Metop-B ASCAT<br>Metop-C ASCAT |

Meridional wind



# Validation framework

Comparison of uncorrected and bias-corrected ECMWF model winds to collocated independent scatterometer observations

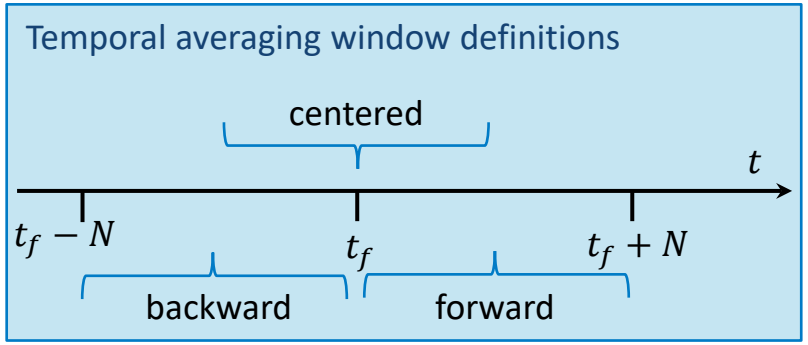
Input data (January 2021)

- ECMWF NWP winds: uncorrected (ERA5) and bias-corrected (ERA5*)
- Scatterometer observations from Metop-A ASCAT and HY-2B HSCAT

- Temporal averaging window for bias corrections
  - Averaging window length
  - Averaging window definition (backward, centered, forward window)

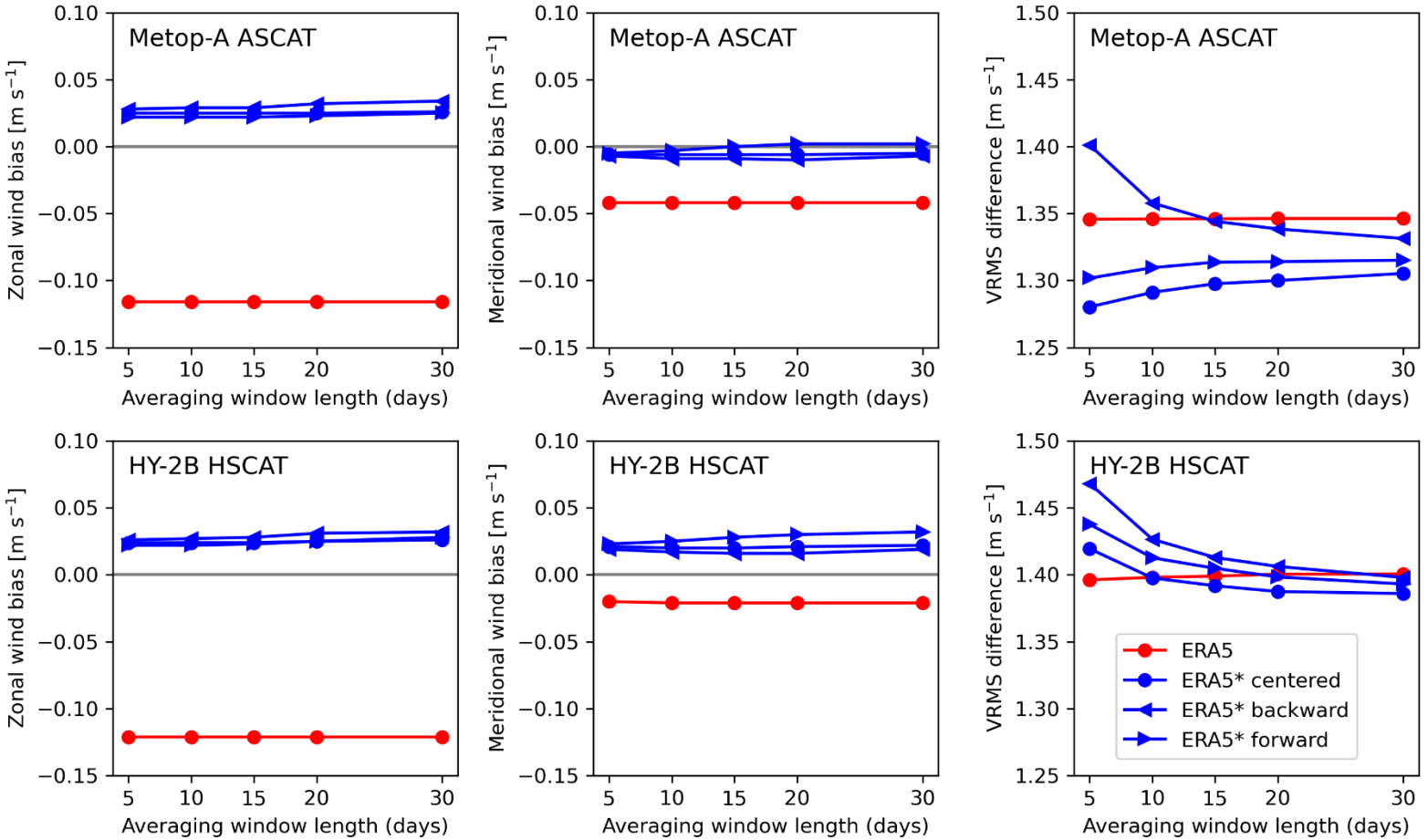
- Scatter plots of individual collocated values

- Spatial maps of scatterometer-model differences (monthly average)



# Validation: averaging window length and definition

- Significant wind bias reduction, consistent for Metop-A ASCAT and HY-2B HSCAT
- Vector root-mean-squared (VRMS) difference for ERA5* similar or smaller than ERA5 for longer windows




Window length selection criteria:
- VRMS similar/lower than ERA5
- Small difference between backward and centered window
- Feasible computation time

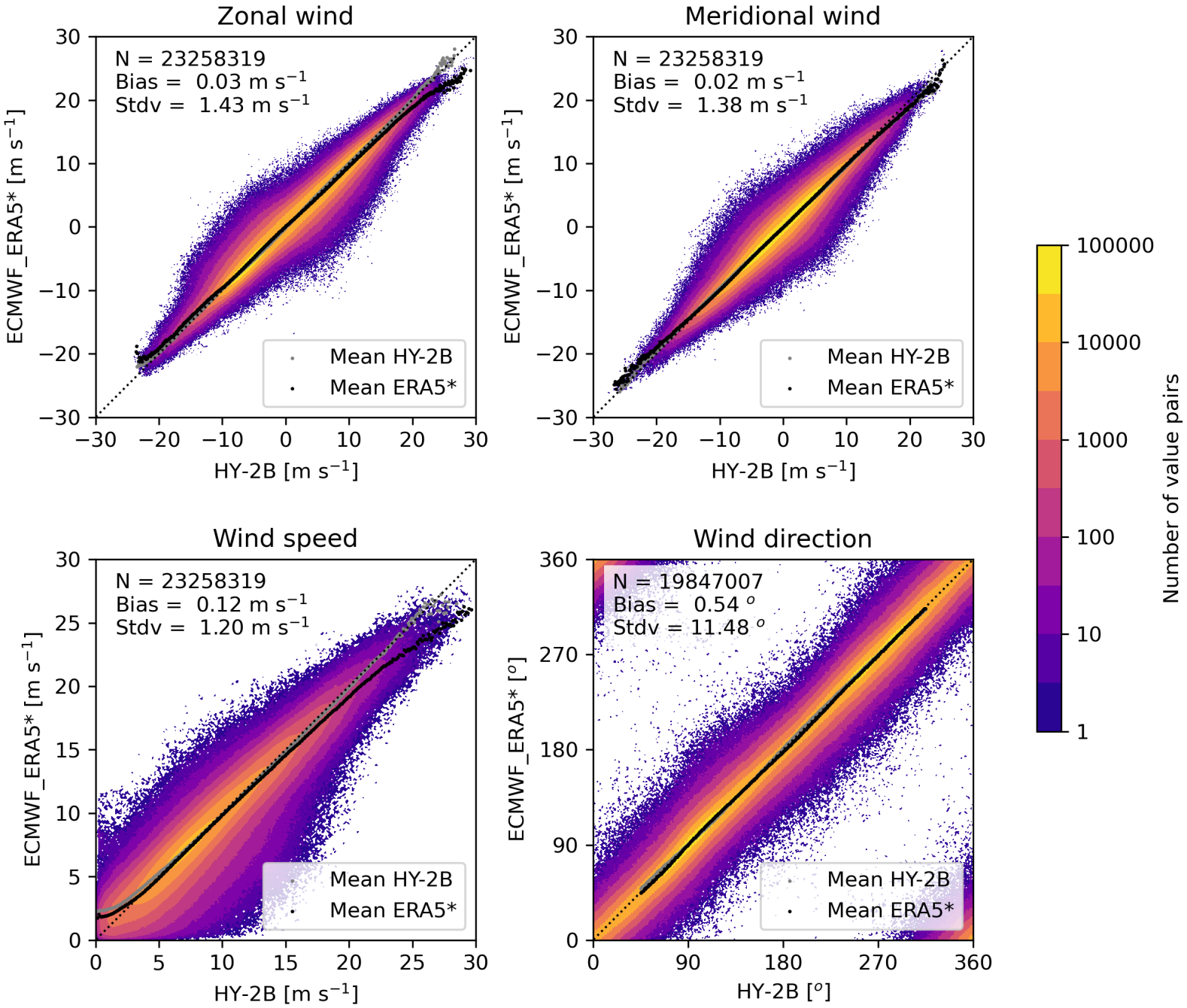
Selected window length: 20 days

| | |
|---|---|
| Period | January 2021 |
| ECMWF model | ERA5 reanalysis |
| Scatterometers | Metop-B ASCAT<br>Metop-C ASCAT |

# Validation: individual values

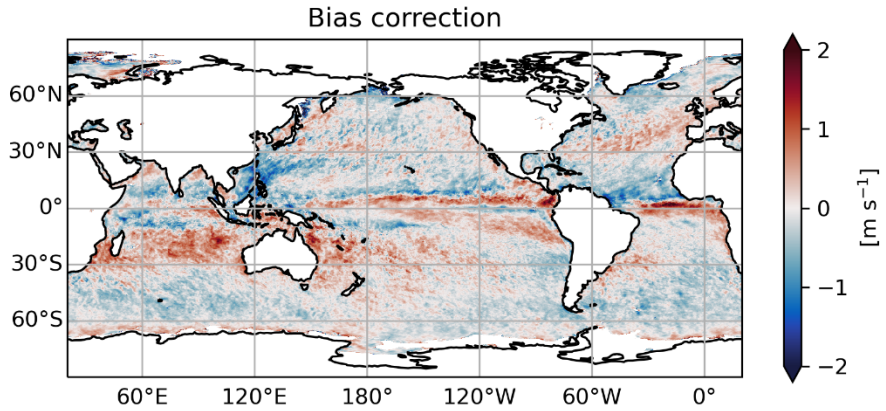
- Generally close correspondence between HY-2B observations and bias-corrected ECMWF model

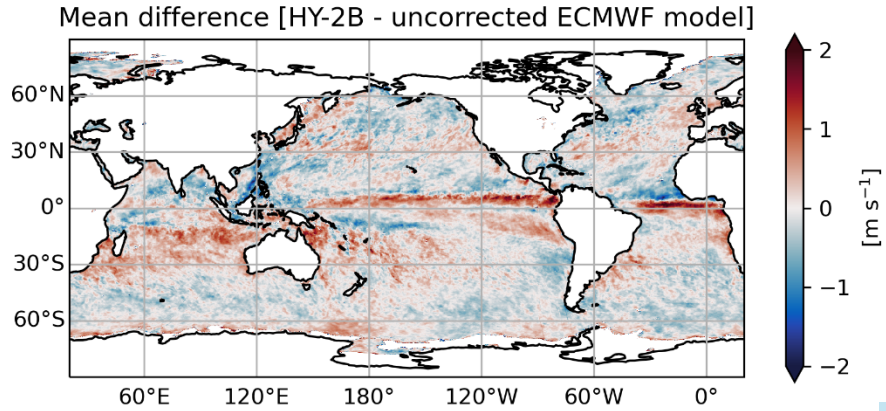
| | |
|---|---|
| Period | January 2021 |
| ECMWF model | ERA5 reanalysis |
| Scatterometers | Metop-B ASCAT<br>Metop-C ASCAT |

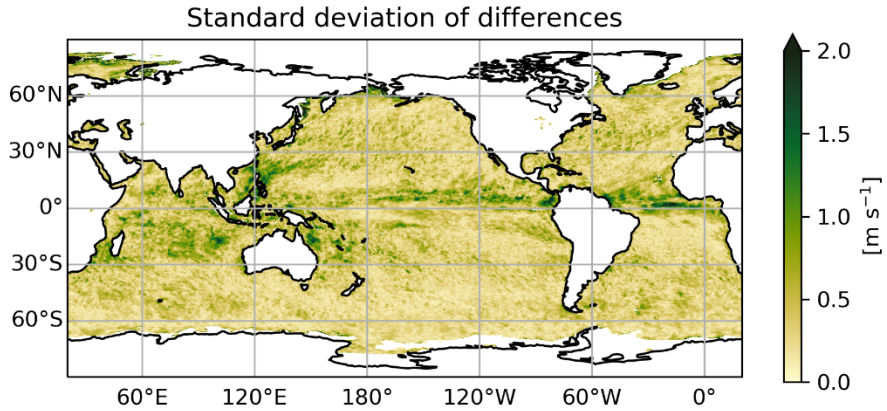


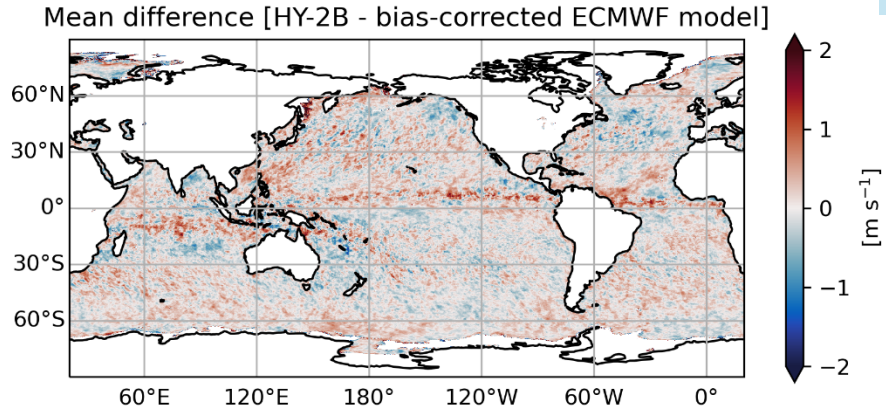
# Validation: comparison to HY-2B HSCAT

- Bias correction very similar to mean difference with collocated independent scatterometer observations
- Persistent biases removed effectively
- Some biases remain in regions with large variability in scatterometer-model differences




| | |
|---|---|
| Period | January 2021 |
| ECMWF model | ERA5 reanalysis |
| Scatterometers | Metop-B ASCAT<br>Metop-C ASCAT |

Meridional wind

# New Copernicus Marine Service L4 wind products

- Produced by KNMI
- Hourly files with bias-corrected ECMWF model fields
- 0.125° horizontal resolution
- Provided variables: wind and stress vector components, divergence and curl
- Statistical variables: bias, standard deviation of differences, difference of variances, number of observations
- Near real-time product (years-2 – day-1)
  - Bias correction based on Metop-B and Metop-C ASCAT scatterometer observations
  - 20-day backward averaging window
  - Planned release: July 2022
- Reprocessed product (1992 – month-4)
  - Bias correction based on available scatterometer observations (varying over time period)
  - 20-day centered averaging window
  - Planned release: November 2022

# Outlook

User feedback is welcome!

Contact:
rianne.giesen@knmi.nl

Refinement of the methodology:

- Outlier removal
- Averaging window definition
- Scatterometer combinations

Validation of the bias-corrected model fields:

- Derivative fields (divergence, curl)
- Coastal regions (comparison with buoys and SAR winds)
- Effect on ocean processes (wind-driven circulation, air-sea interaction)