Royal Netherlands
Meteorological Institute
Ministry of Infrastructure
and Water Management

Hourly Surface Wind Forcing Products from ERS in the 1990's

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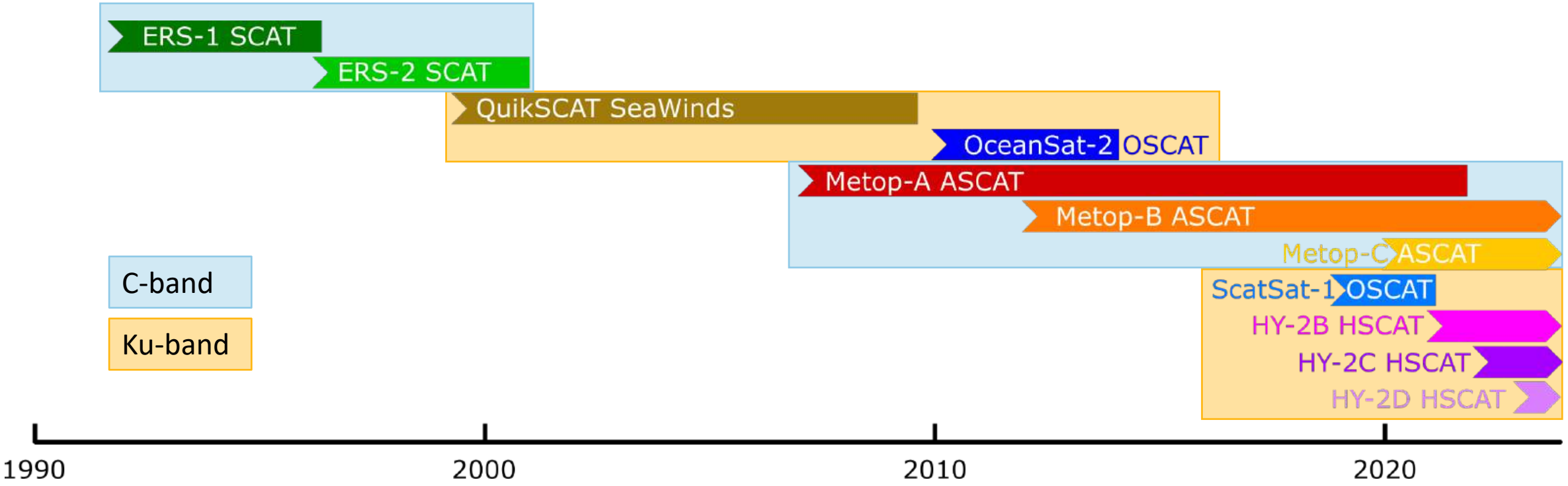
and colleagues from KNMI, ICM (Barcelona) and NUIST (Nanjing)

Scatterometer time line

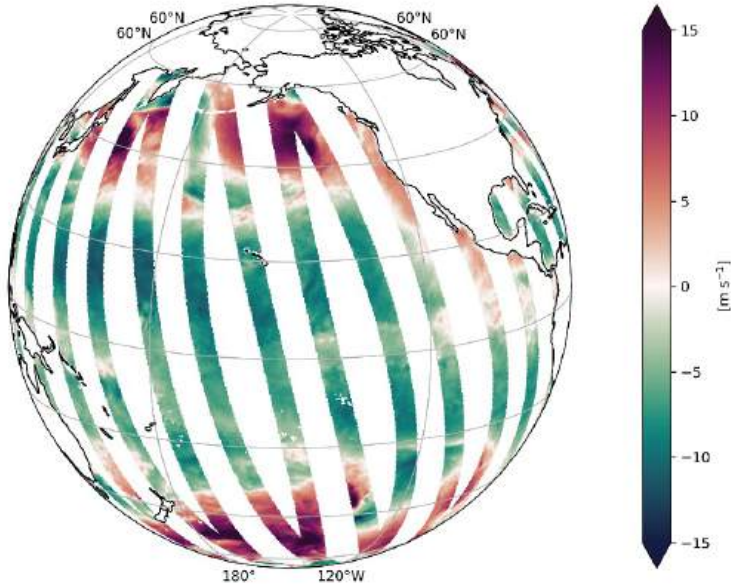
- KNMI et al. provide intercalibrated products for all scatterometers at L2, L3 and L4
- Provides a wind vector series since last century with unprecedented accuracy
- Cone metrics intercalibration ERS and ASCAT



L3 wind products

- Scatterometer observations for one satellite instrument
- Provided variables: surface wind and stress vector components, divergence and curl
- Include ECMWF model wind and stress fields collocated at L2
- Intercalibrated L2 provided by EUMETSAT OSI SAF

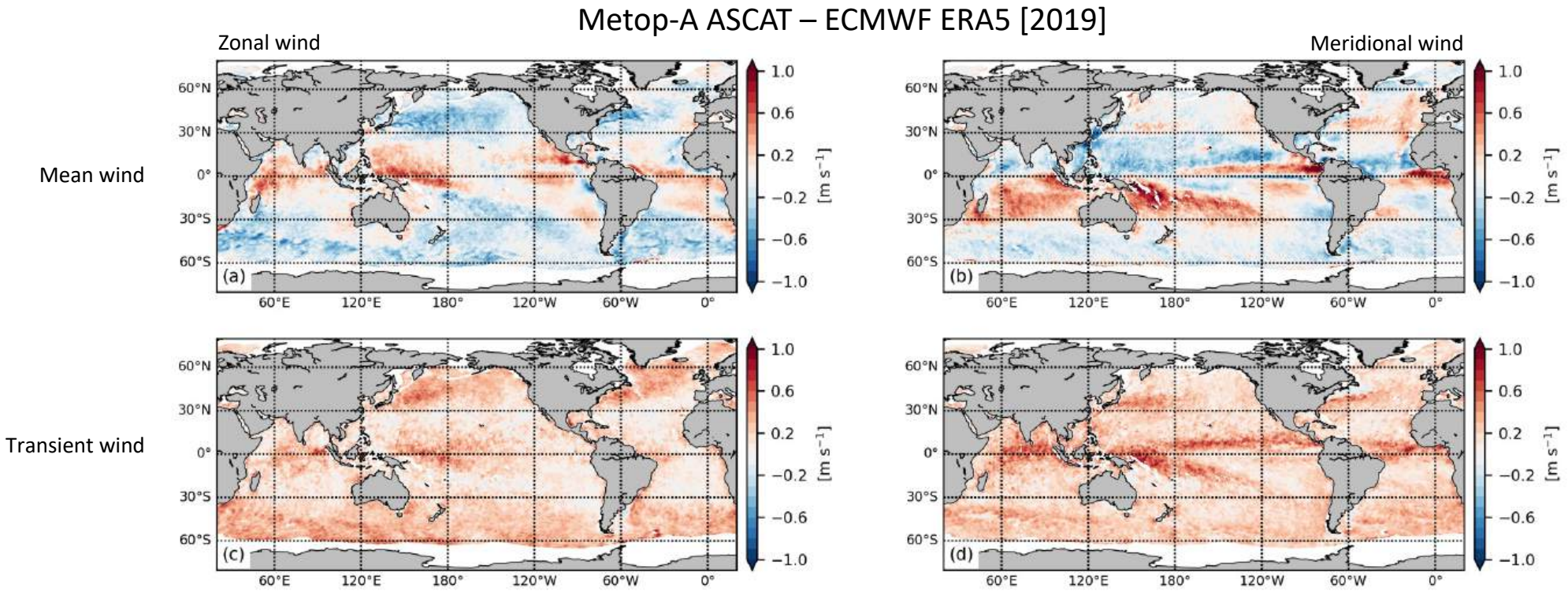
Zonal wind Metop-A ASCAT ASC



Product	ECMWF forecasts	Number of instruments	Horizontal grid	Period	Update
NRT daily	Operational	7	0.125° 0.25° 0.50°	2016 - -1 day	Daily
MY daily	ERA5	6	0.125° 0.25° 0.50°	1991 - -4 months	Monthly

NWP model biases

- Gridded L3 averages over 20+ days tell us:
- Persistent biases between scatterometer observations and ECMWF model winds, called SC
- Lack of small-scale variability in ECMWF model winds, lack of div and curl

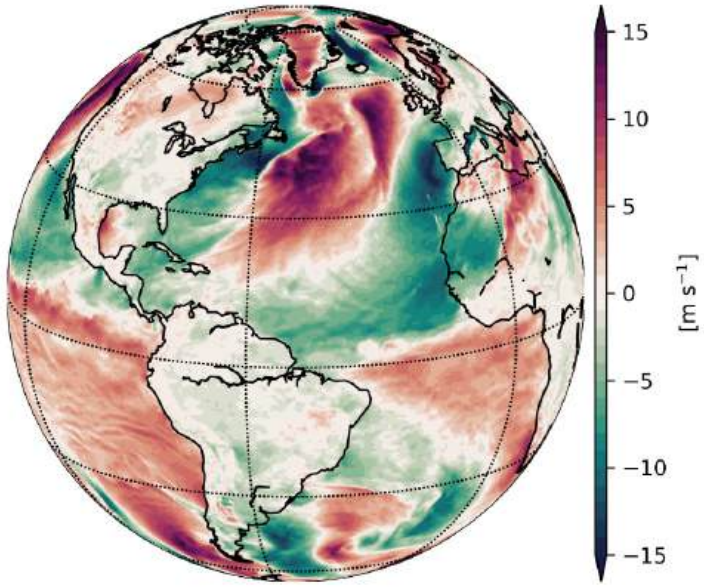


Belmonte Rivas, M. and A. Stoffelen (2019): *Characterizing ERA-Interim and ERA5 surface wind biases using ASCAT*, Ocean Sci., 15, 831–852, doi: 10.5194/os-15-831-2019.

L4 wind products

- Bias-corrected ECMWF model fields by adding SC
- Provided variables: surface wind and stress vector components, divergence and curl
- Statistical variables: bias, standard deviation of differences, difference of variances, number of observations
- Available from Copernicus Marine Service,
  ERS added in June ‘24 from 1994 and later

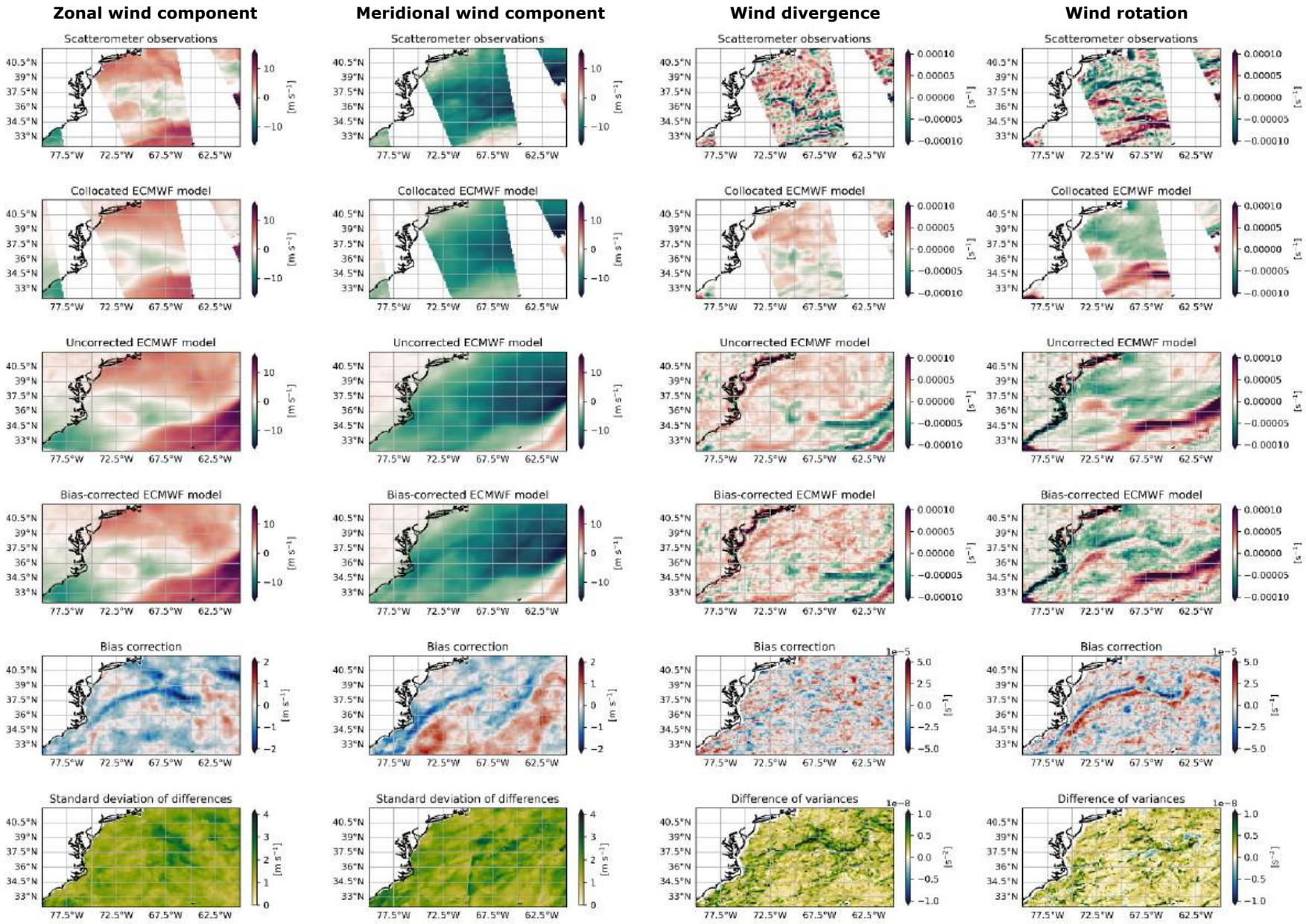
Meridional wind



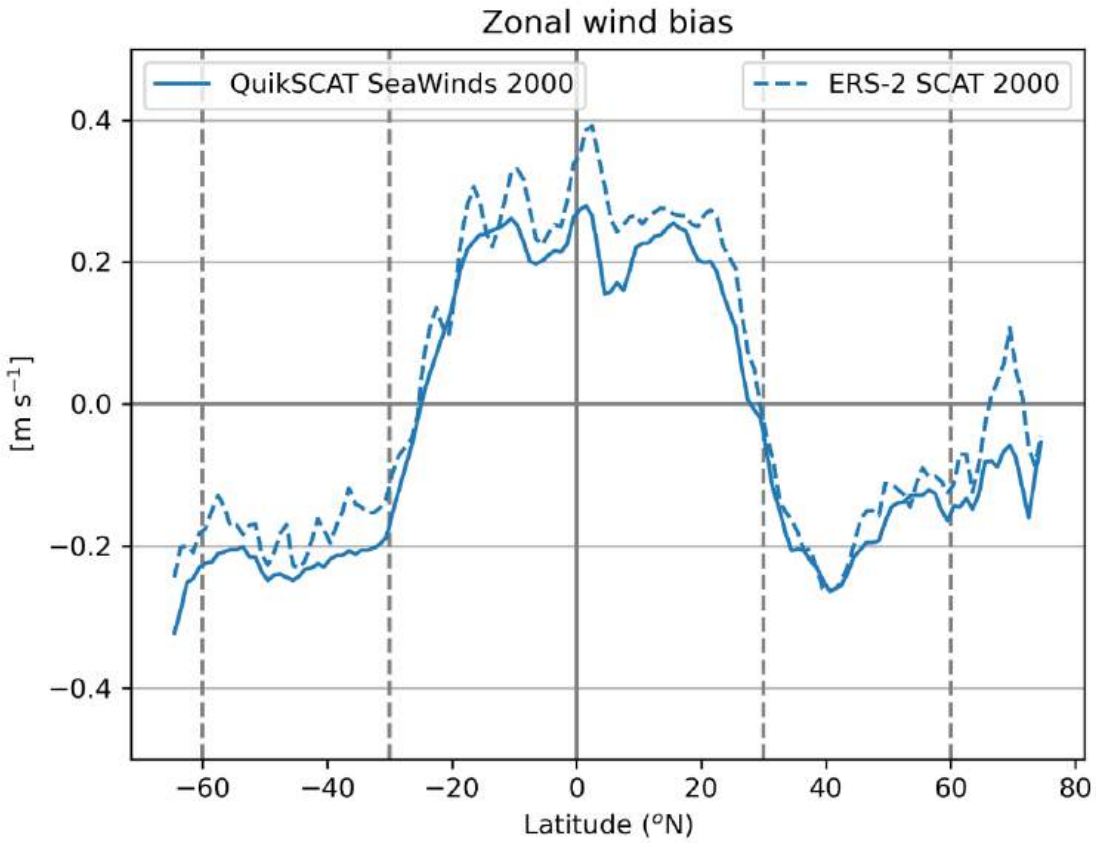
Product	Released	ECMWF forecasts	Averaging window	Horizontal grid	Period	Update
NRT hourly	July 2022	Operational	20 days (backward)	0.125°	-2 years - -1 day	Daily
MY hourly	November 2022	ERA5	20 days (centered)	0.125° (ASCAT) 0.25° (other)	1999 - -4 months	Monthly
MY monthly	November 2022	ERA5	Full month (centered)	0.25°	1999 - -4 months	Monthly

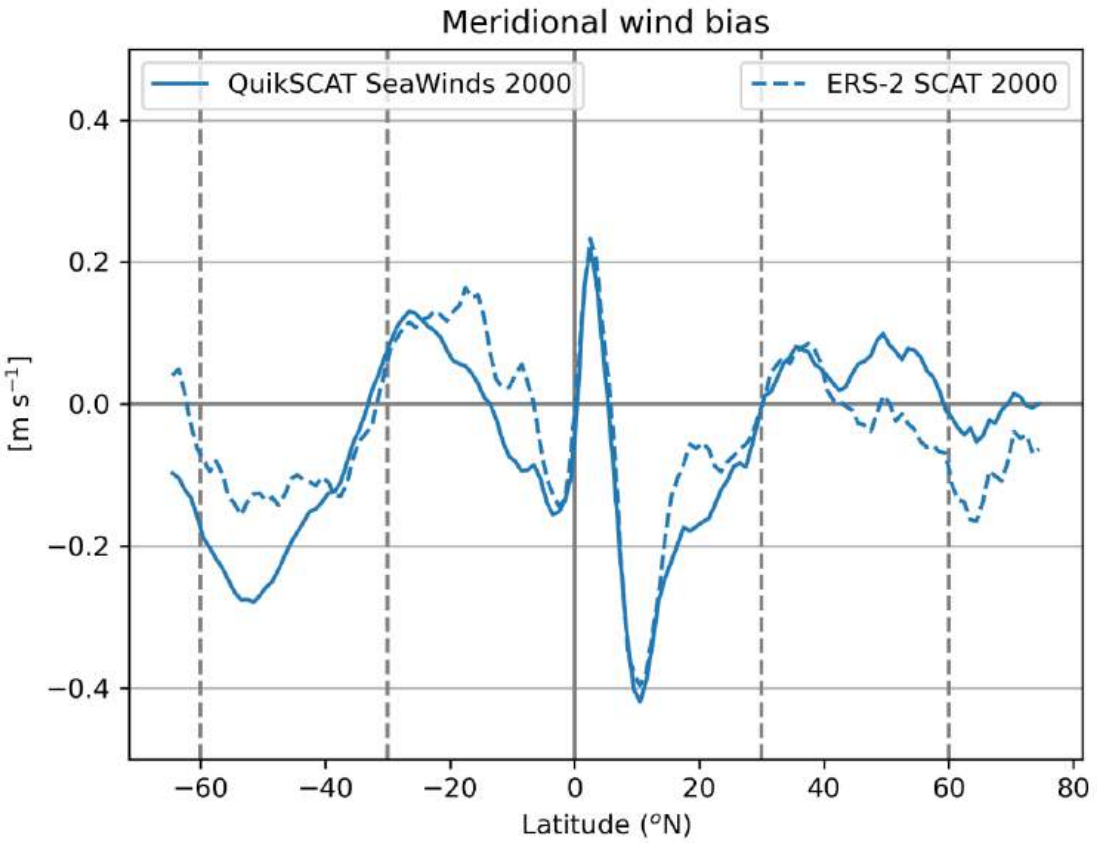
L3 and L4 variables

Gulfstream region
2 February 2023
SC: Metop-B/C ASCAT
ECMWF ERA5



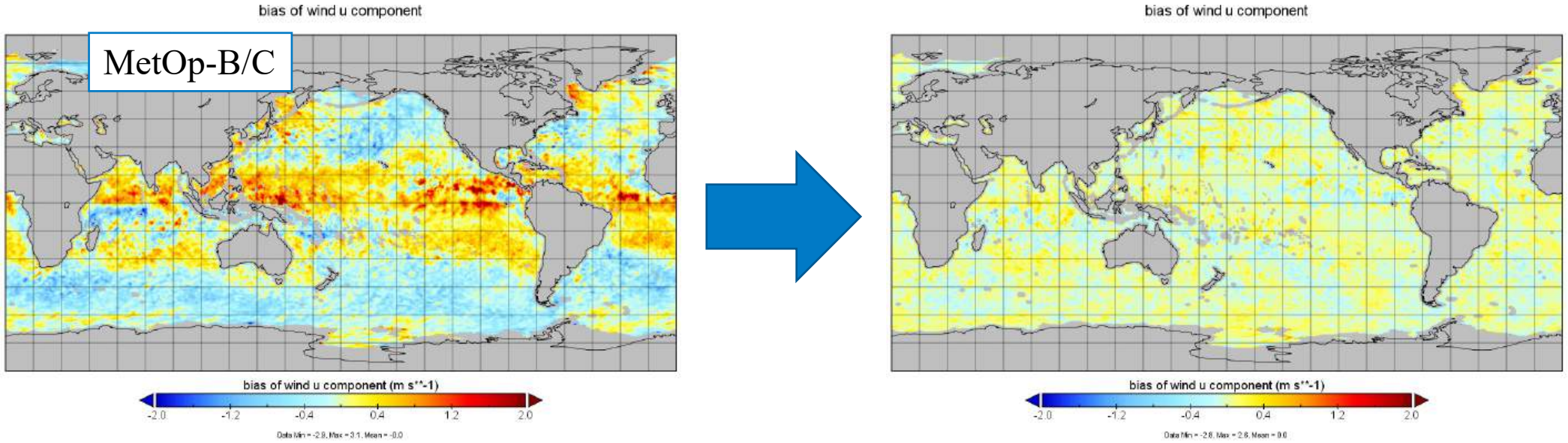
Bias comparison between QuikSCAT and ERS-2





Applications

- Improved wind forcing/fluxes for physical ocean models, SC sensitivity studies > Copernicus Marine Service
- Link with physical processes to improve model parameterizations > ICM NN, EUMETSAT fellow, KNMI/ECMWF
- Use bias-adjusted scatterometer observations in data assimilation > tests at ECMWF by De Chiara et al.
- Validation of new scatterometers with improved background winds > Zhen Li

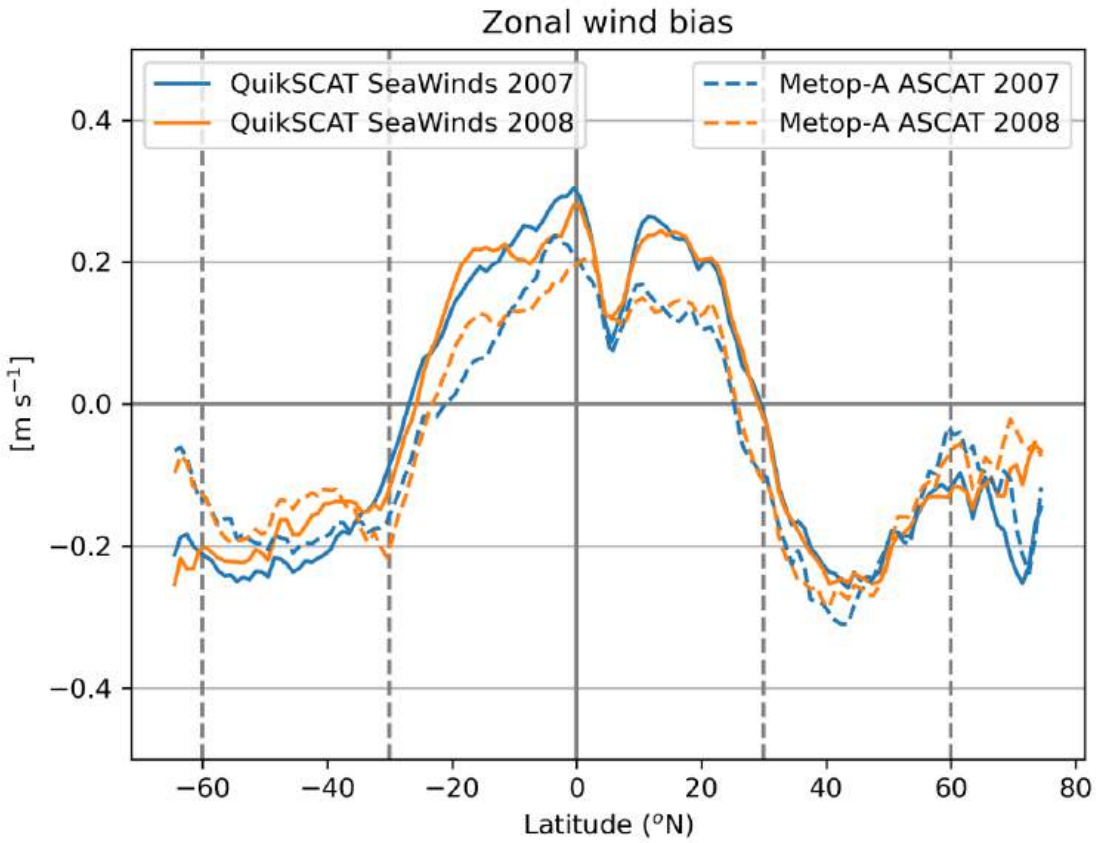


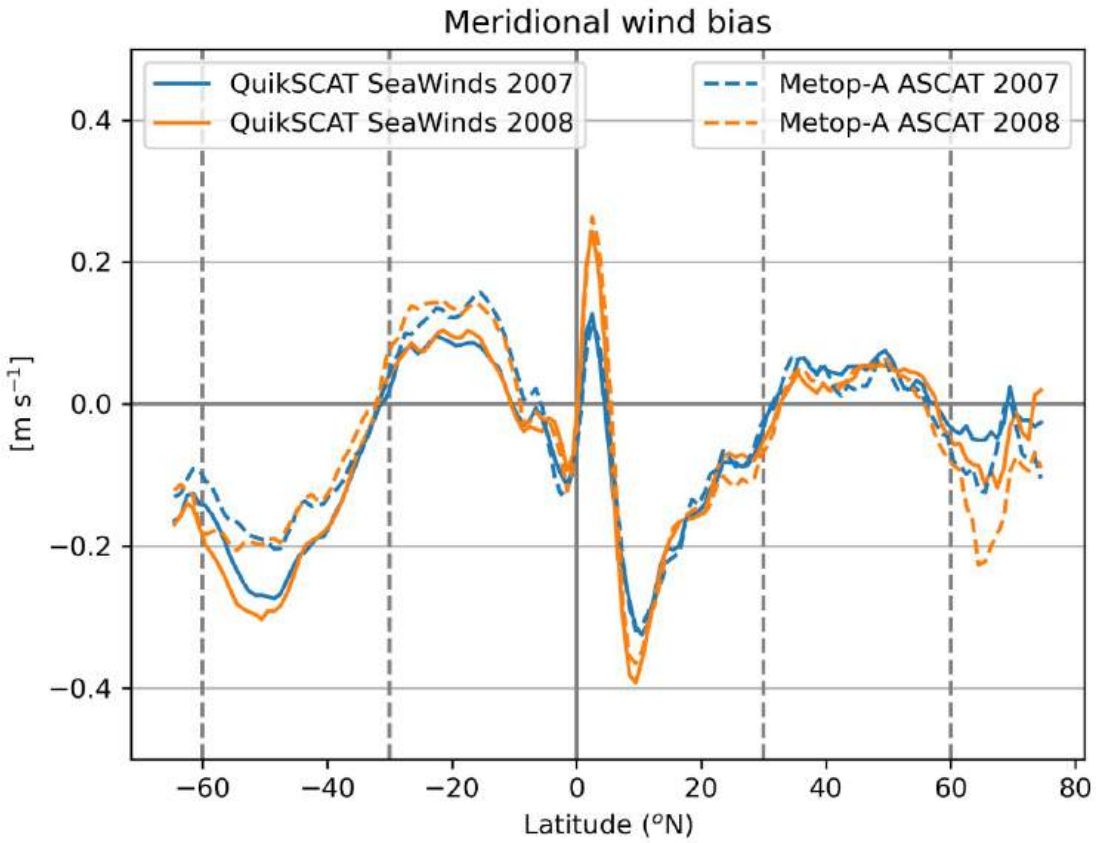
Summary

- Significant persistent NWP model biases with scatterometer observations
- 20+ day temporally-averaged differences can be used to produce bias-corrected NWP model fields
- Seasonal cycle in biases is stronger than interannual variability
- Gradual changes in bias correction magnitude over multi-annual periods
- Generally very good correspondence between scatterometer instruments, differences in model bias are due to calibration, MSS processing or QC
- Backward extension with ERS-1 and ERS-2 is possible using longer averaging windows
- 1991-1994 needs to deal with a few periods with a 3-day repeat cycle and is work in progress

Backup slides

Bias comparison between QuikSCAT and Metop-A

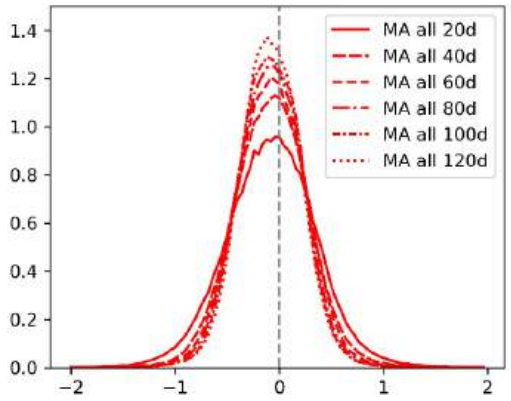




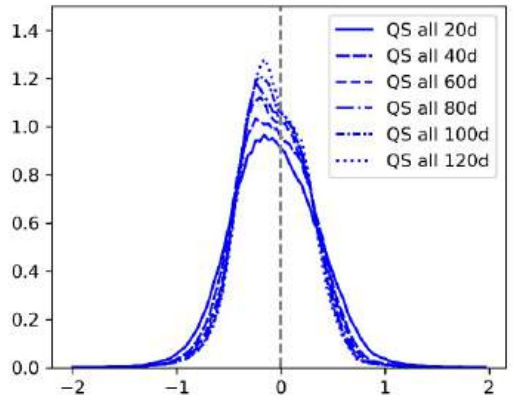
Bias comparison between QuikSCAT and Metop-A

Zonal wind bias

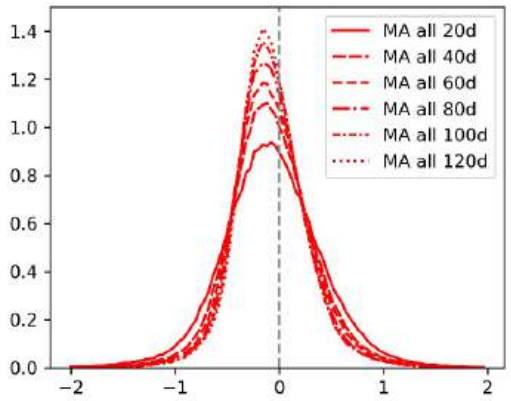
Metop-A

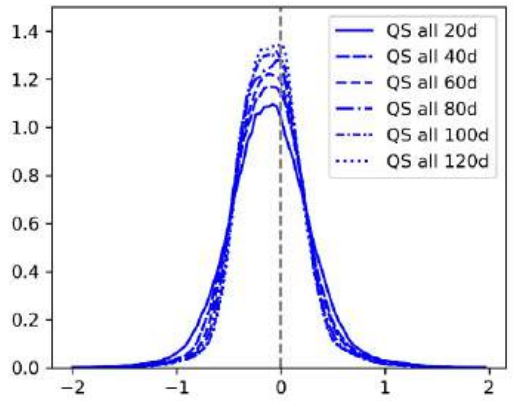


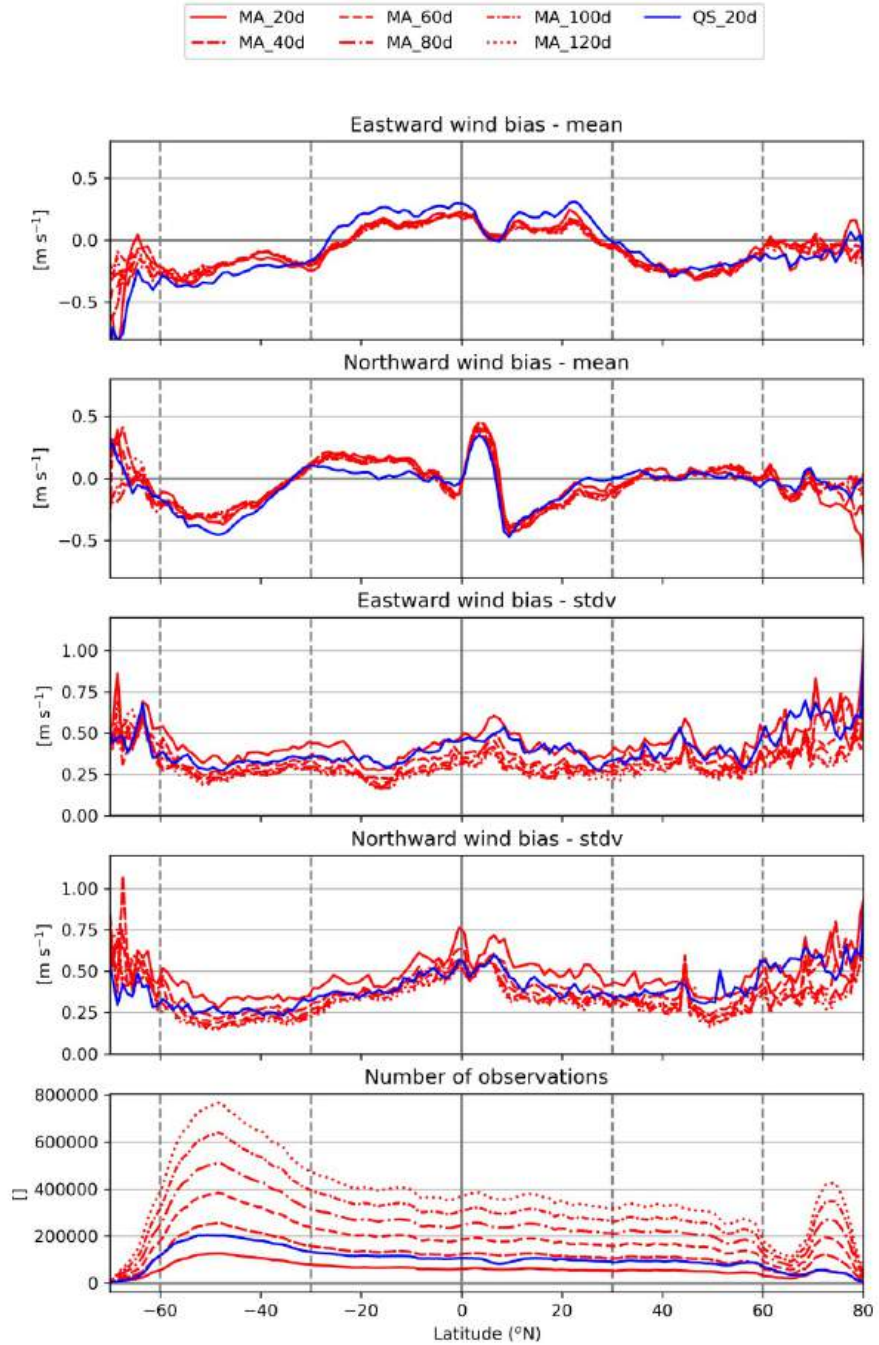
QuikSCAT



Meridional wind bias





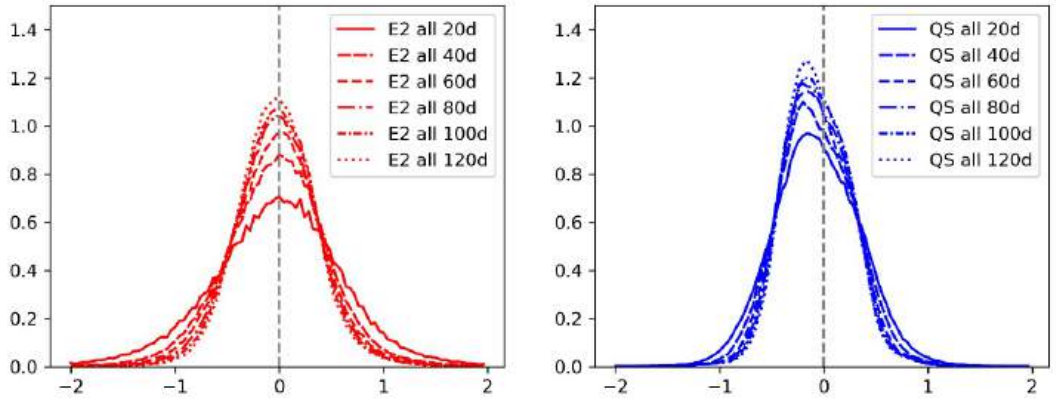


Bias comparison between QuikSCAT and ERS-2

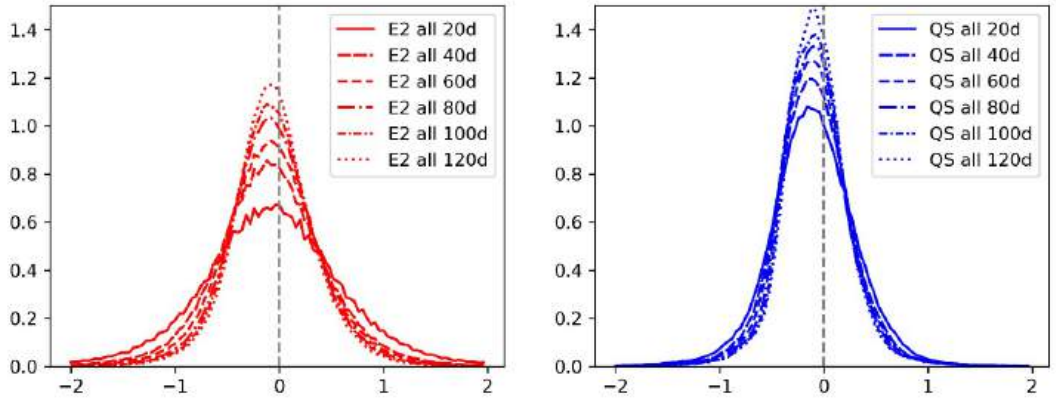
ERS-2

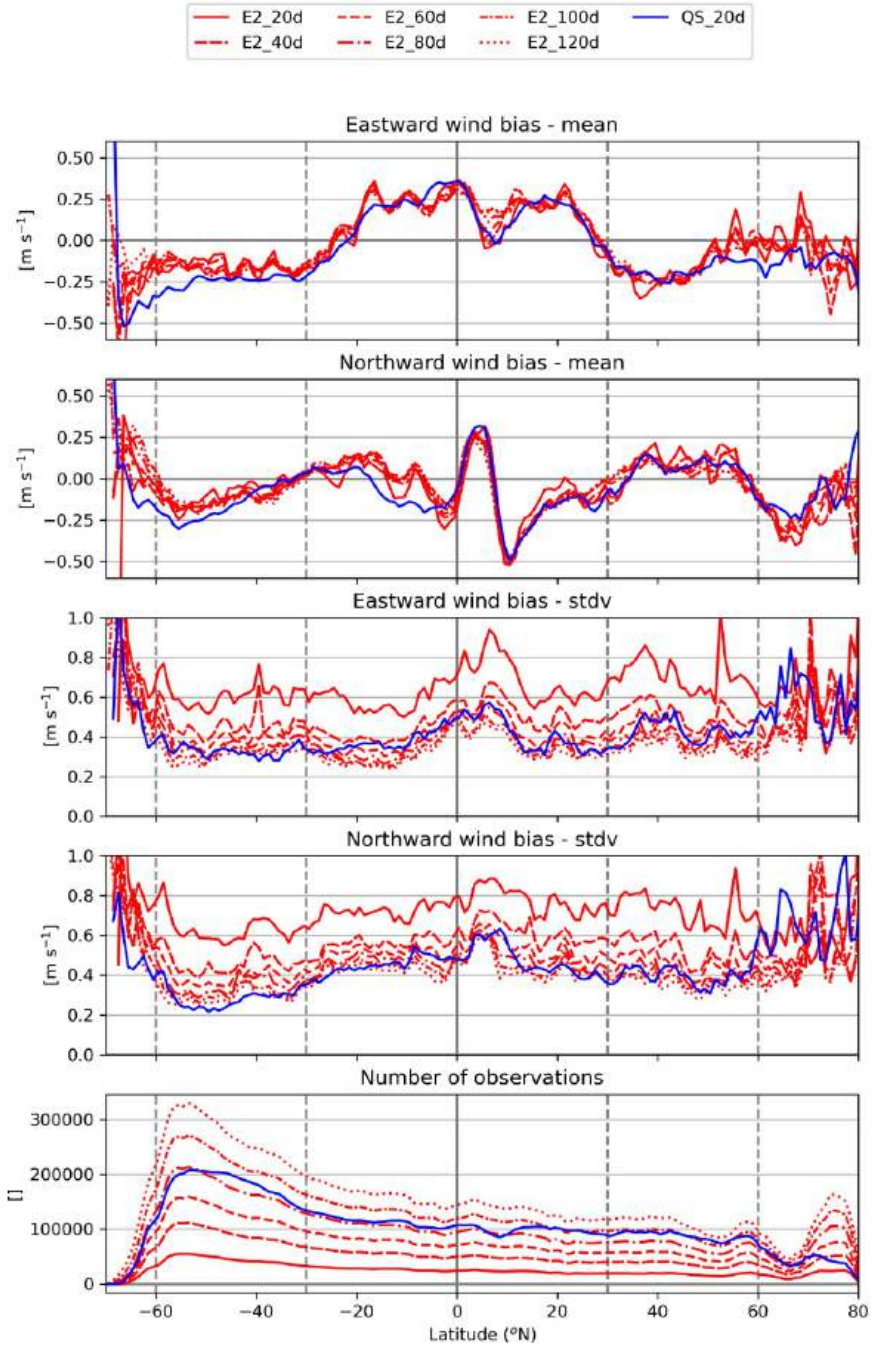
Zonal wind bias

QuikSCAT



Meridional wind bias



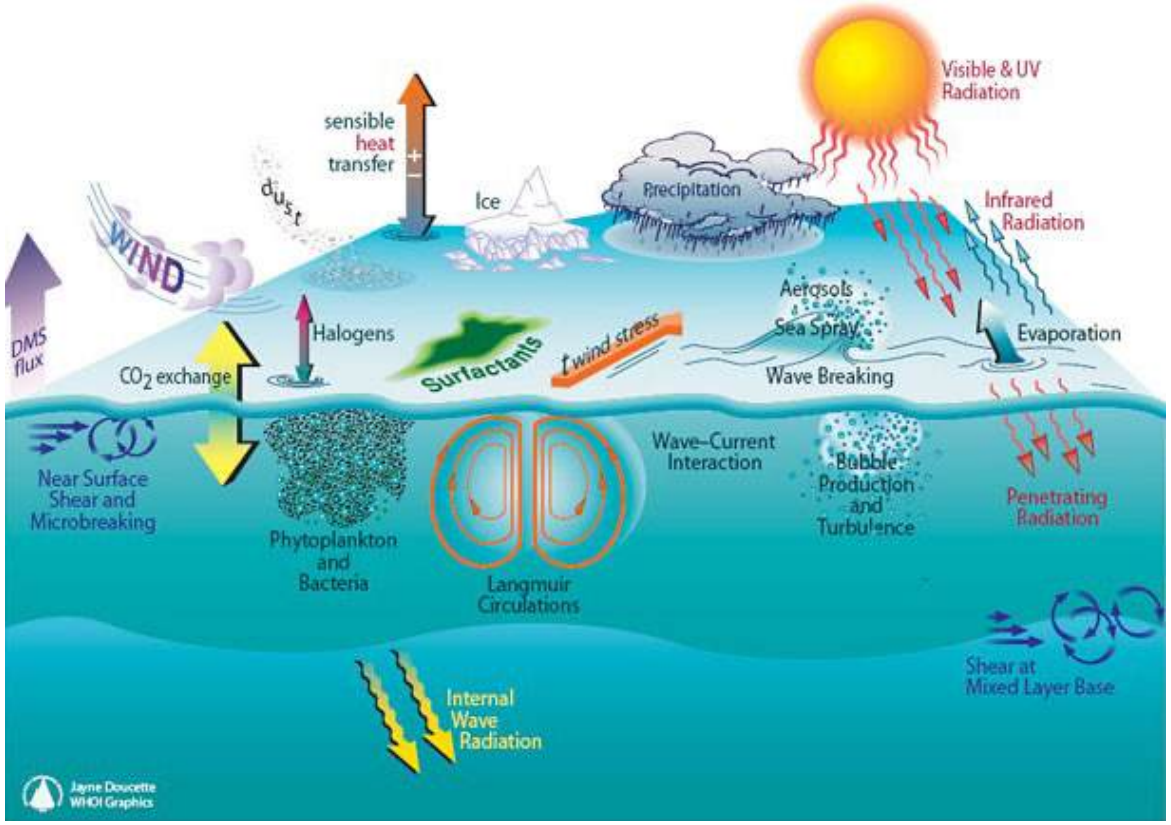


Context

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

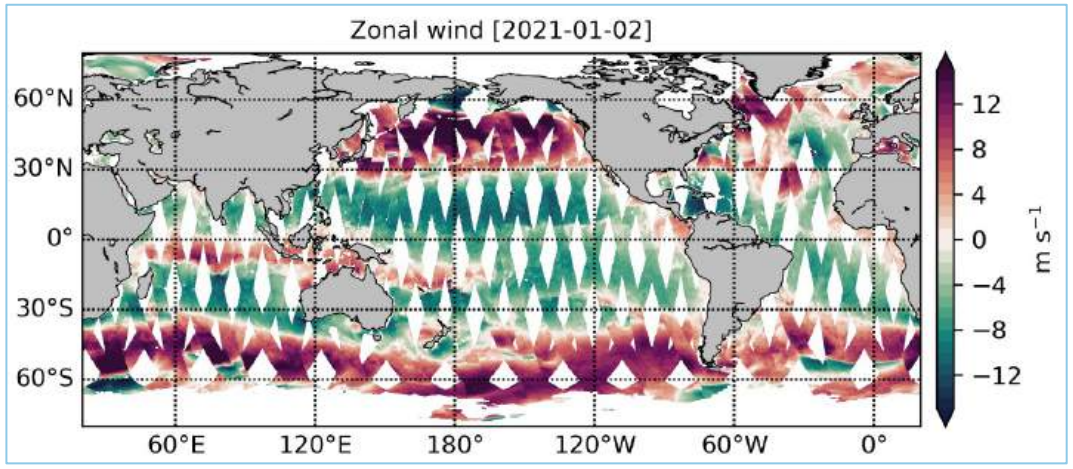
To accurately represent these processes in physical ocean models, global fields with high spatial and temporal resolution are needed



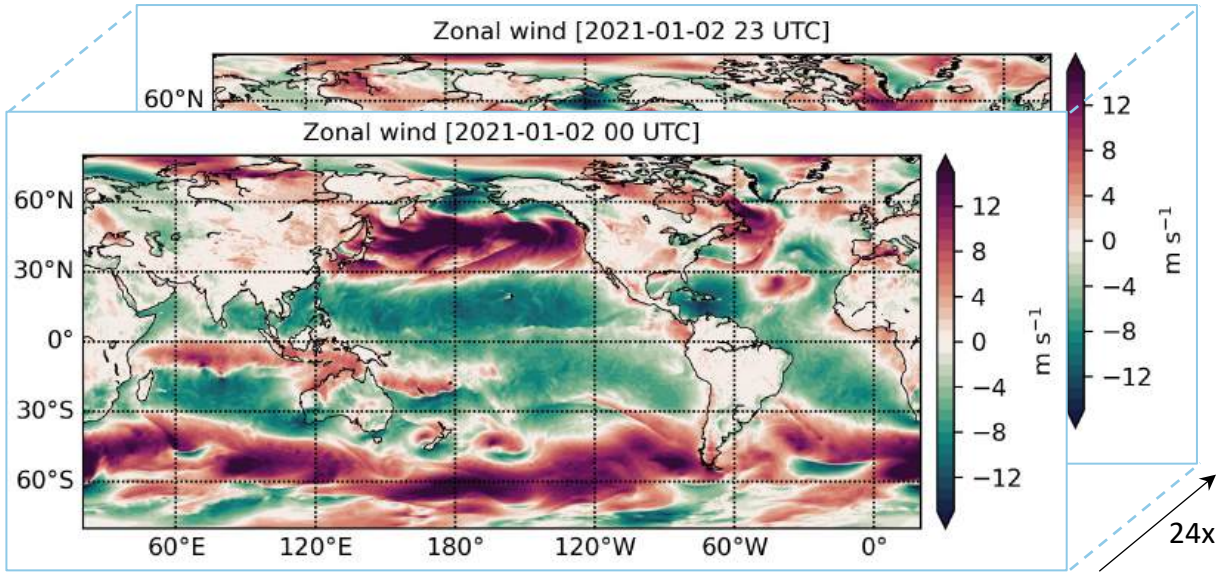
Source: Woods Hole Oceanographic Institution

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)

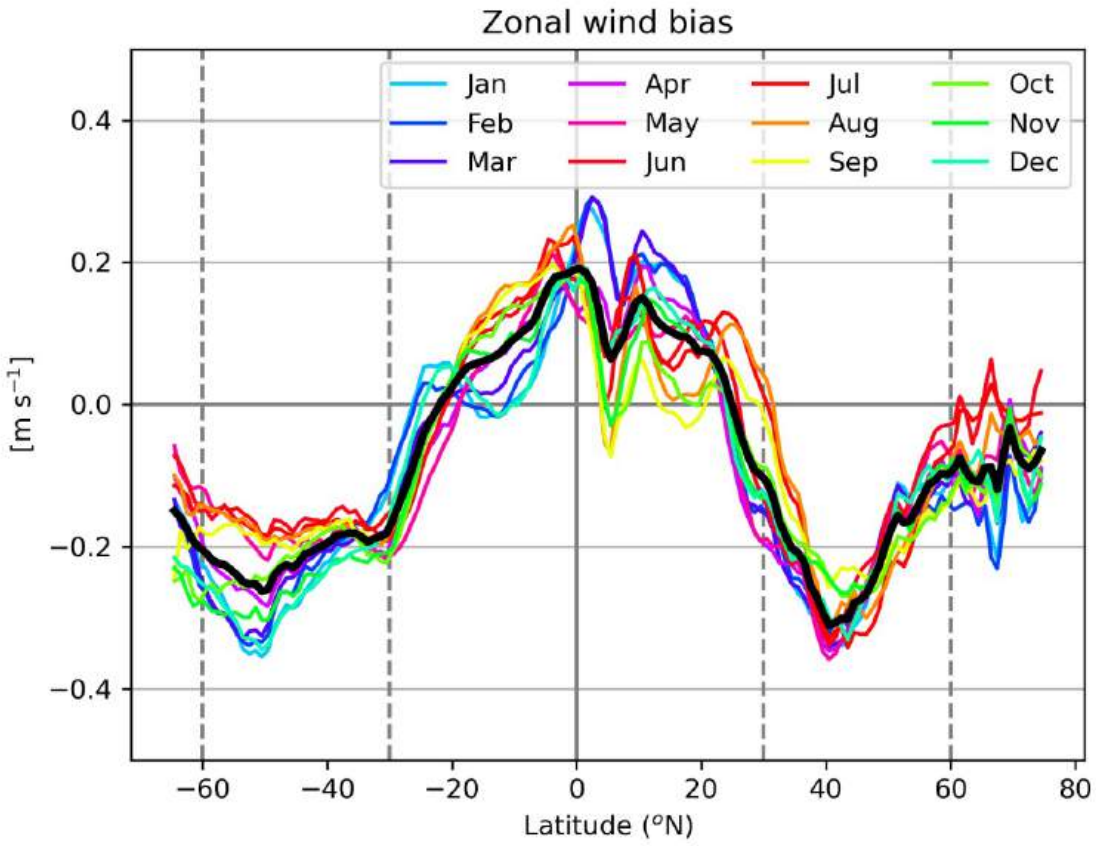


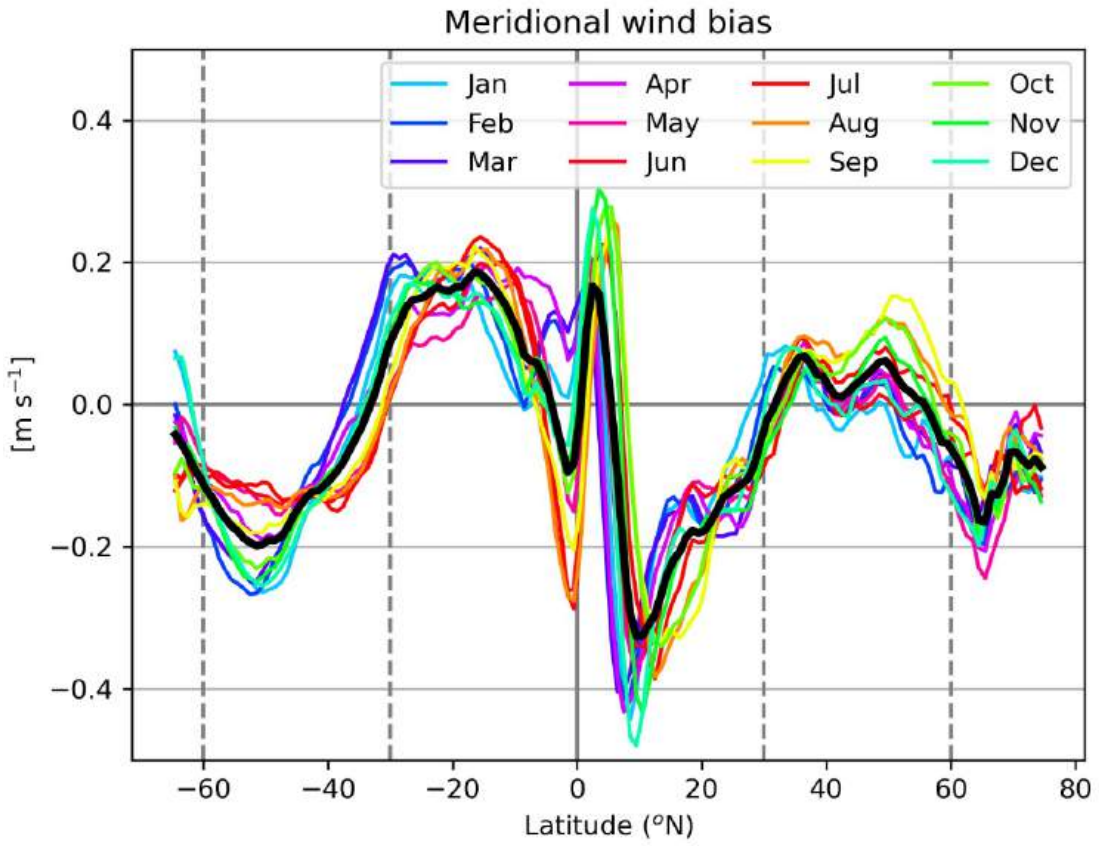
NWP model daily coverage (ECMWF ERA5)

Seasonal bias changes

- Zonal wind biases are positive in the tropics and negative at higher latitudes
- Strong latitudinal gradients in the meridional wind biases in the tropics
- Changes in magnitude and location of maxima/minima

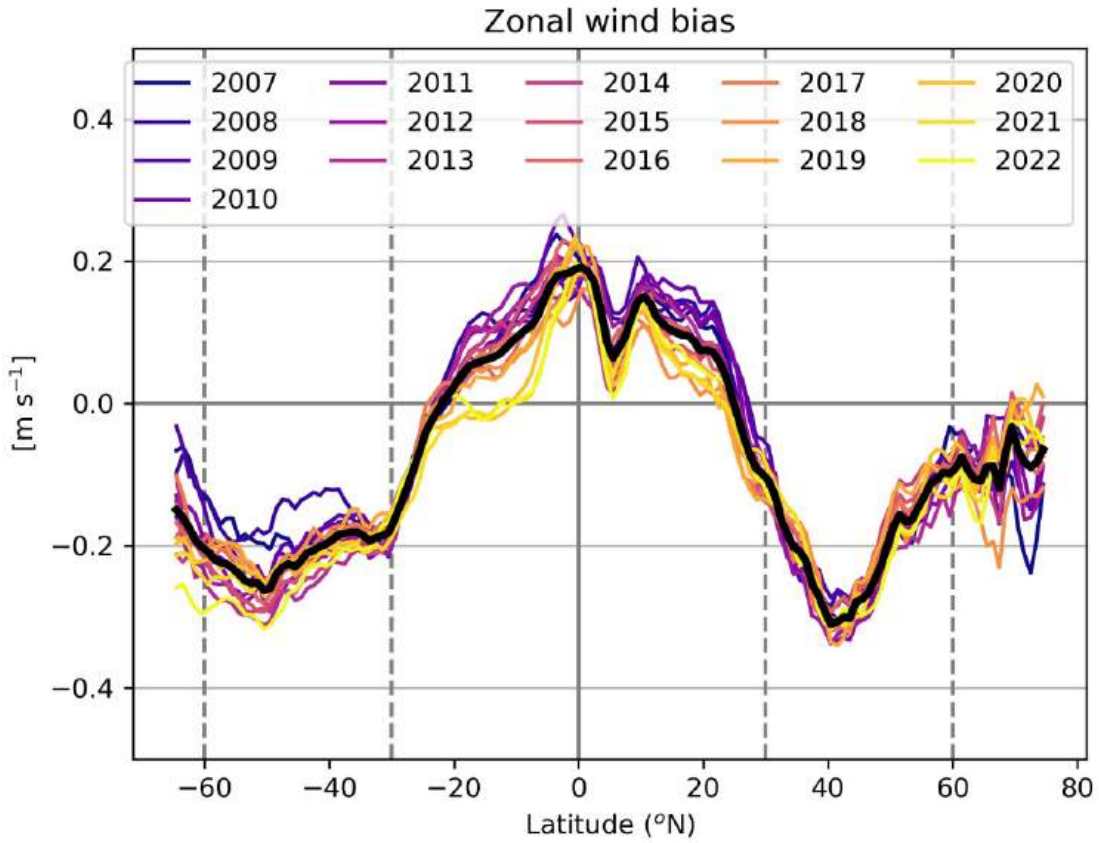
SC: Metop-A/B/C ASCAT
ECMWF ERA5
2007-2022

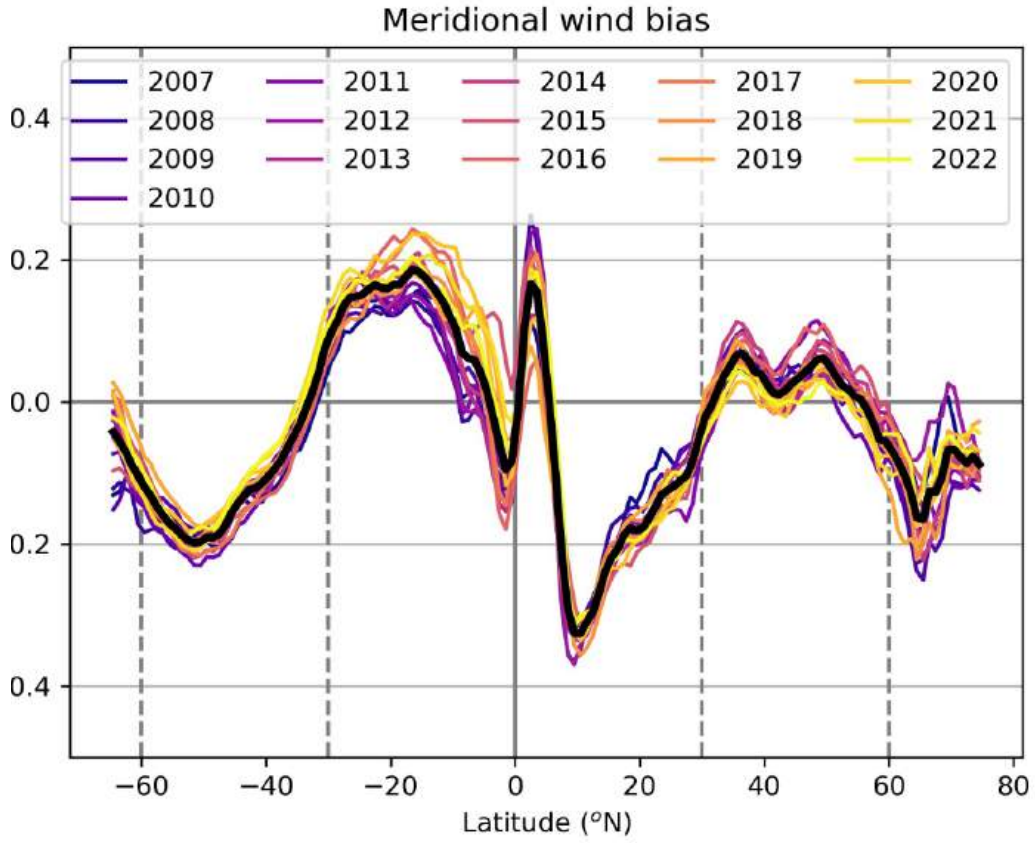




Interannual variability

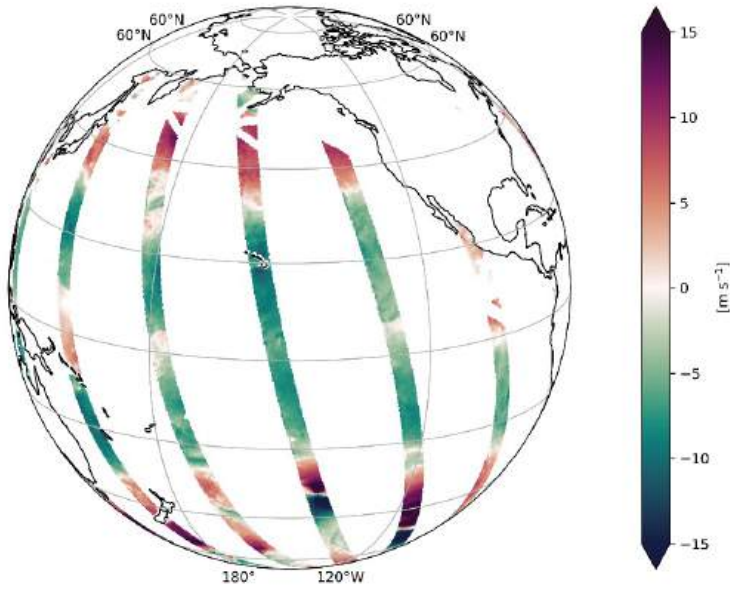
- Interannual variability in scatterometer corrections is smaller than seasonal variability
- Gradual shift in latitudinal patterns over the years: to be investigated



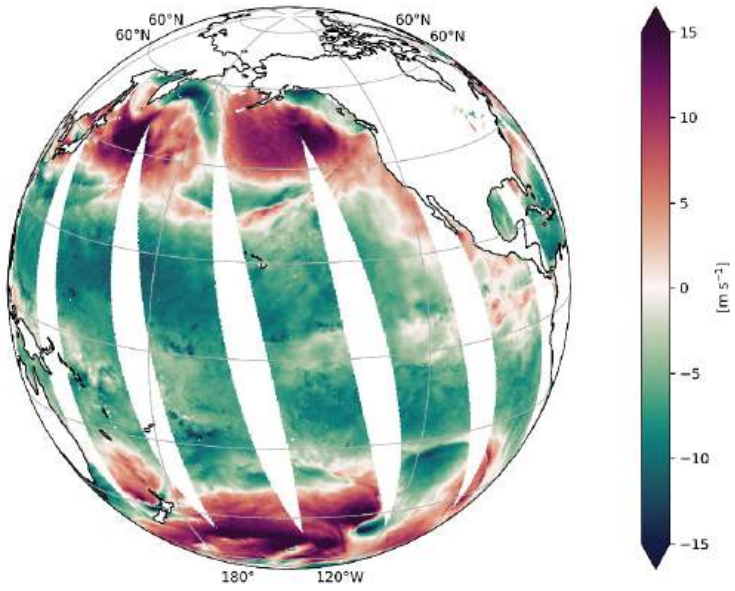


Scatterometer spatial coverage

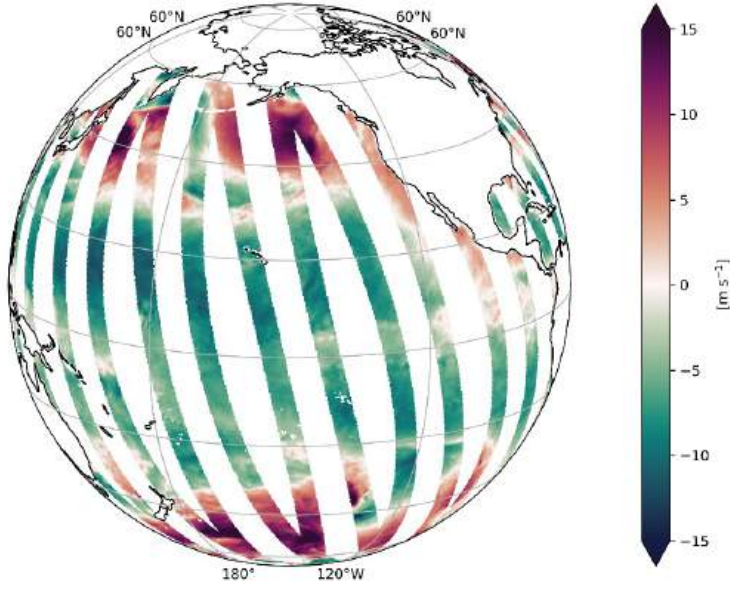
Zonal wind ERS-2



Zonal wind QuikSCAT



Zonal wind Metop-A



Zhixiong’s slide !

Bias comparison between QuikSCAT and Metop-A

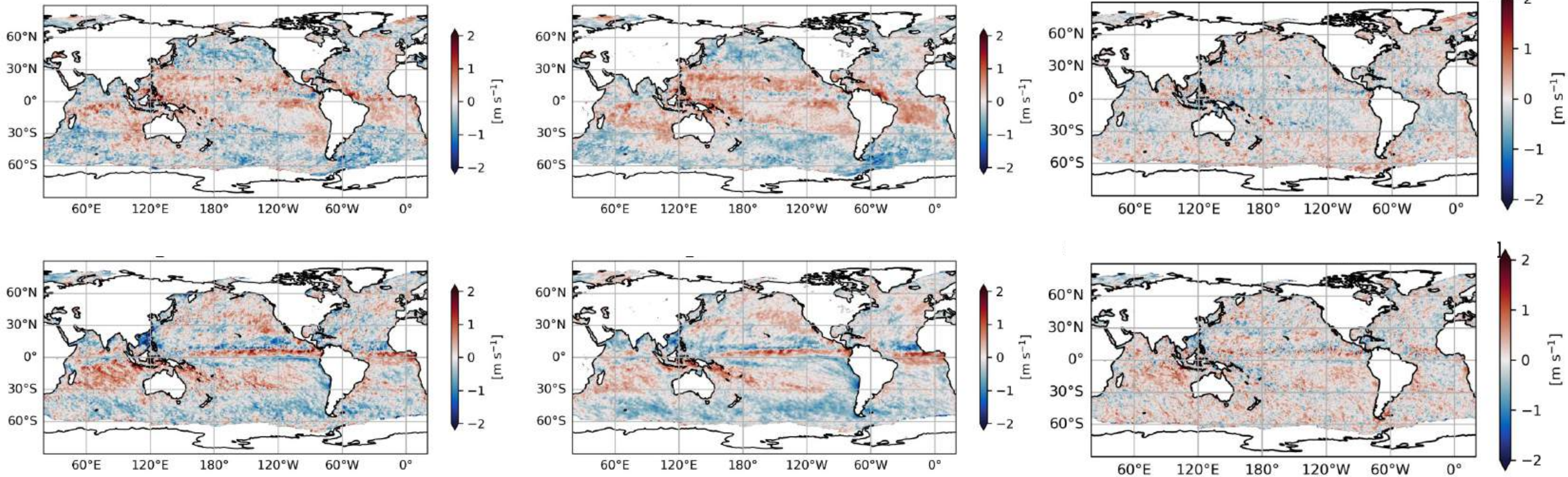
Metop-A ASCAT

QuikSCAT Seawinds

Metop-A - QuikSCAT

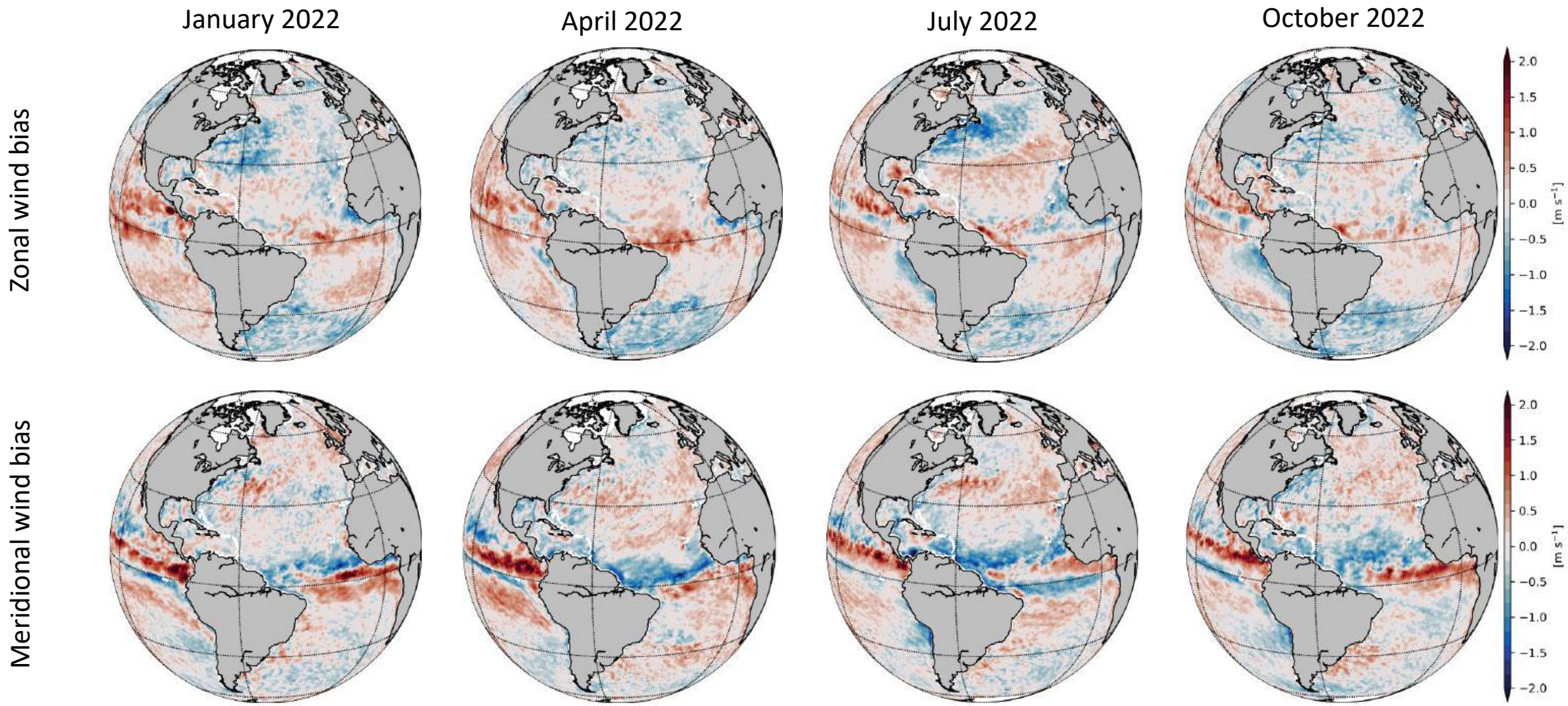
Zonal wind bias

Meridional wind bias



SC: Metop-B/C ASCAT
ECMWF ERA5

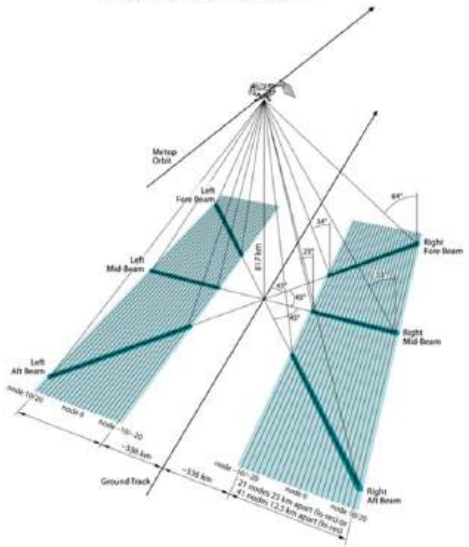
Seasonal bias changes



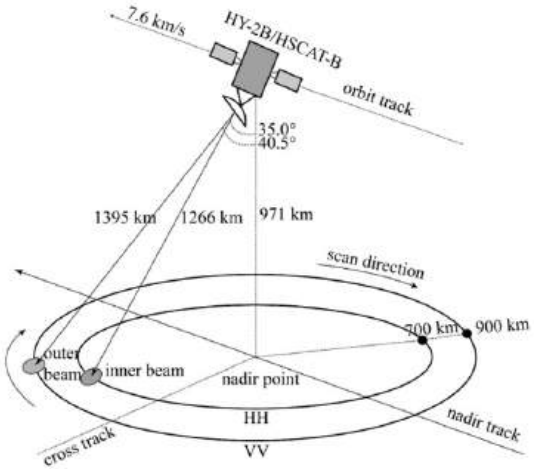
Scatterometer wind observations

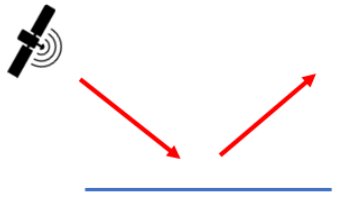
- Active microwave instrument
- Backscatter of the signal increases with increased ocean surface roughness
- Wind speed and direction are derived from the backscatter using a geophysical model function

Fixed fan-beam

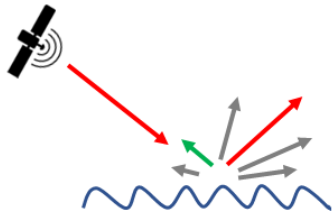


Rotating pencil-beam

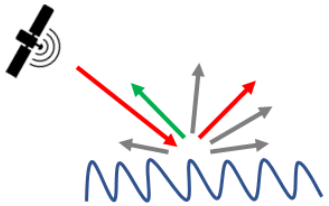




No wind
Ocean Surface is flat so the satellite signal reflected in a single direction



Moderate wind
A bit of roughness on the ocean Surface, some backscatter goes back to the satellite



Intense wind
Ocean Surface is very rough, thus more backscatter reaches the satellite

Scatterometer correction

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

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)*

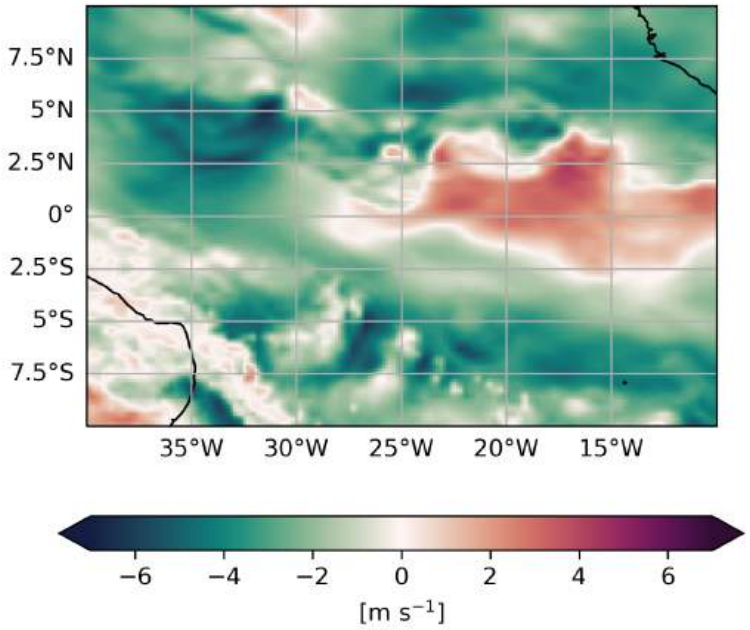
Trindade, A., M. Portabella, A. Stoffelen, W. Lin and A. Verhoef (2020), *ERAstar: A High-Resolution Ocean Forcing Product*, IEEE Trans. Geosci. Remote Sens., 1-11, doi: 10.1109/TGRS.2019.2946019.

Bias-corrected ECMWF fields

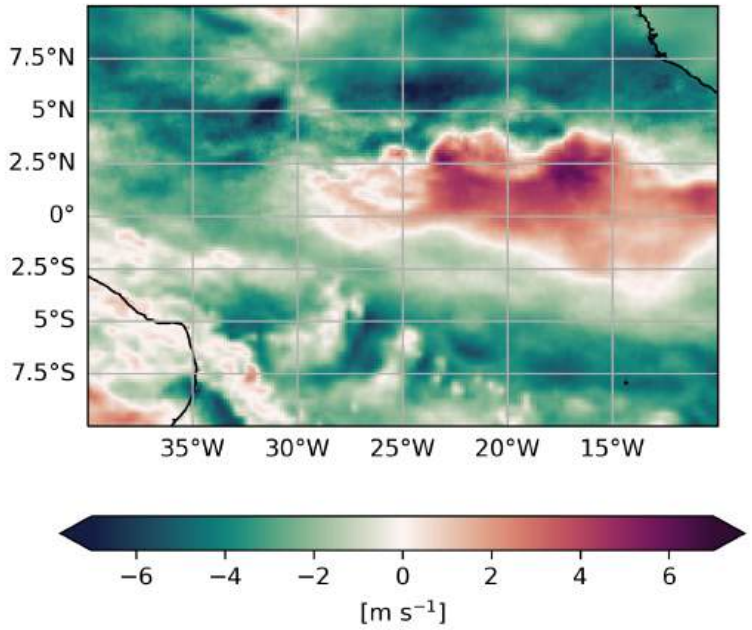
$$u_{10s}^{NWP*}(i,j,t_f) = u_{10s}^{NWP}(i,j,t_f) + SC(i,j,t_f)$$

Meridional wind

ERA5



Bias-corrected ERA5



Bias correction (20 days)