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REPRESENTATIVENESS OF COASTAL STATIONS FOR VERIFYING OPEN-WATER 10 METRE WIND FORECASTS

Nelson Shum & Tim Bullock

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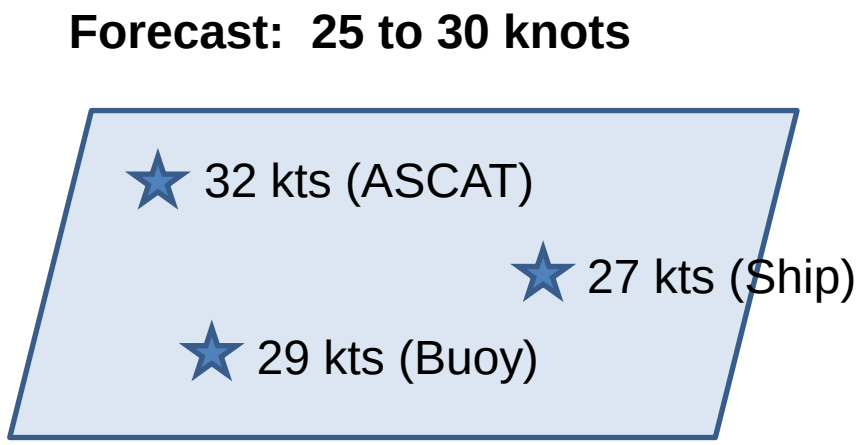
Canada

PROTOTYPE MARINE VERIFICATION SYSTEM

In 2018, Environment and Climate Change Canada started assessing the performance of its marine wind forecasts using a prototype of an automated verification system.

The system is designed to make use of all available observations to verify the forecasts.

THE MULTI-VALUED APPROACH



- Compares a forecast range within a given window in space and time against the corresponding range of observations, allowing all available observations to be included;

- Details can be found in Tim Bullock's presentation at the 7th International Verification Methods Workshop (2017) at Berlin, Germany.

AVAILABLE MARINE WIND OBSERVATIONS

Source	Pros	Cons
Buoy	• Excellent temporal coverage	• Poor spatial coverage • Measurements not taken at 10 metres • Not reliable above 30 knots*
Ship	• Measurements taken at various points of the forecast area	• Poor spatial coverage • Measurements not taken at 10 metres • Poor temporal coverage • Winds perturbed by the ship's superstructure
Coastal	• Excellent temporal resolution	• Poor spatial coverage • Measurement not taken at 10 metres • Measurements affected by terrain
ASCAT	• Reported values calibrated to estimate conditions at 10 metres • Good spatial coverage • Reliable up to 60 knots*	• Poor temporal resolution • Not available near the coast or over ice covered waters

* Manaster, Ricciardulli, and Meissner 2019: Validation of High Ocean Surface Winds from Satellites Using Oil Platform Anemometers. *J. Atmos. Oceanic Technol.,* **36**, 803-815, https://doi.org/10.1175/JTECH-D-18-0116.1

CORRECTION OF WIND SPEEDS TO 10 METRES

- Since forecast wind speeds are intended to represent values at 10 metres above sea level, observations are adjusted accordingly.

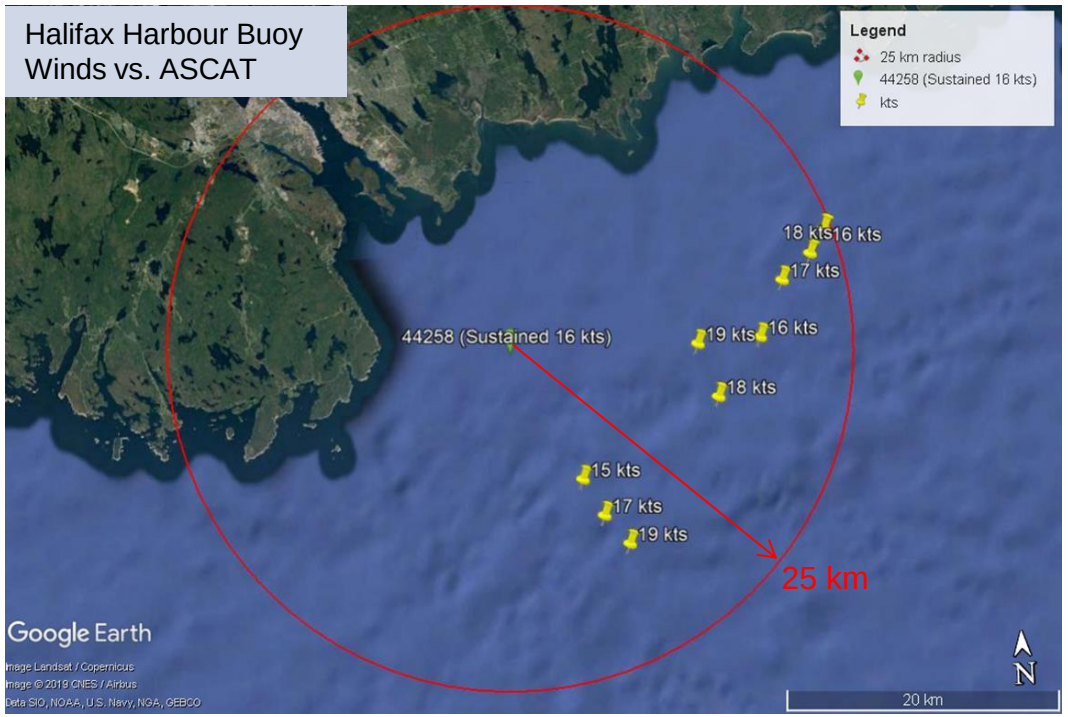
- The correction algorithm was provided by our American counterparts, who developed the algorithm based on the W. T. Liu et al. (1979) paper*.

* Liu, W. T., K. B. Katsaros, and J. A. Businger, 1979: Bulk Parameterizations of Air-Sea Exchanges of Heat and Water Vapor Including Molecular Constraints at the Interface, Journal of Atmospheric Science, Vol. 36, 1722-1735

CORRECTING LAND STATION WINDS

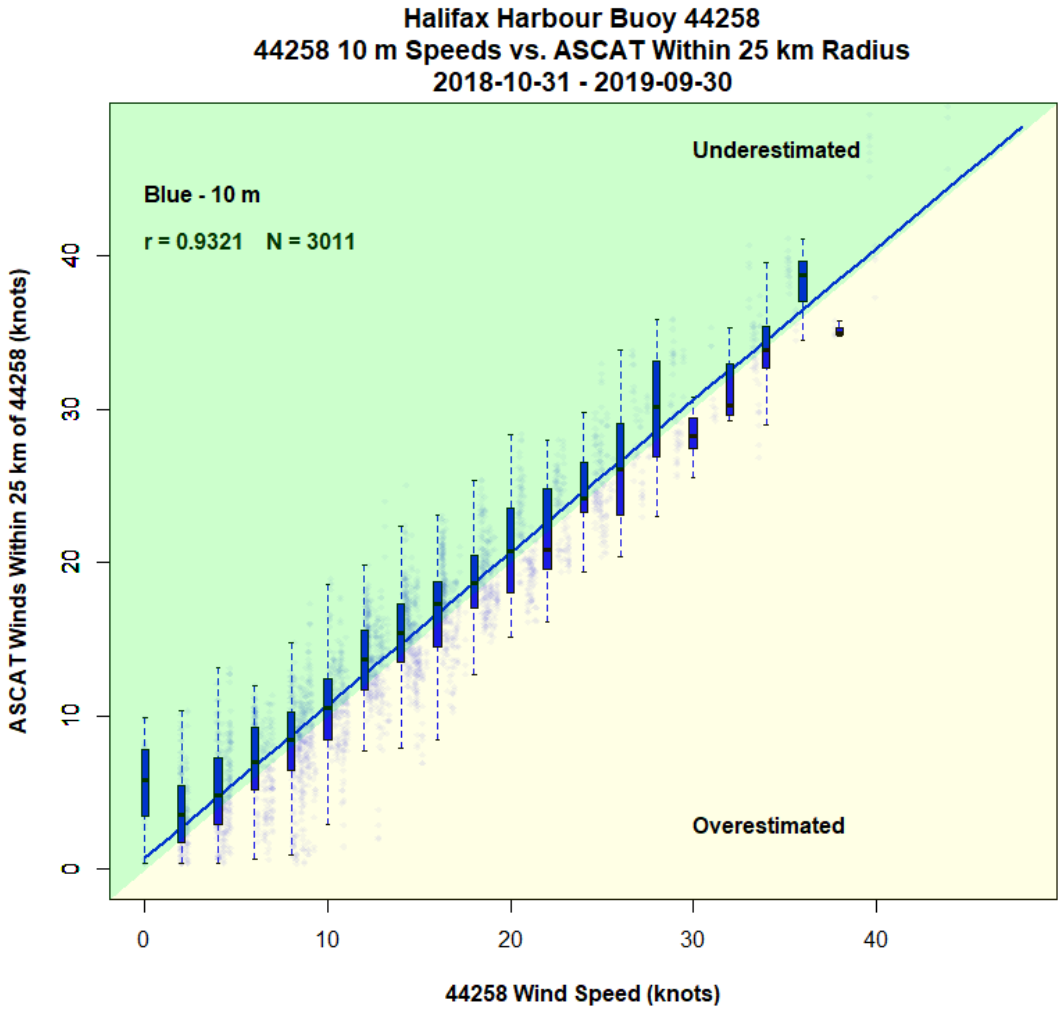
- The correction algorithm is intended for observations over water (e.g. buoys and ships).
- Is the algorithm also suitable for land observations that are well-exposed to the marine environment?
- Comparing observations from coastal stations against ASCAT data will help us test this assumption.

GATHERING THE DATA



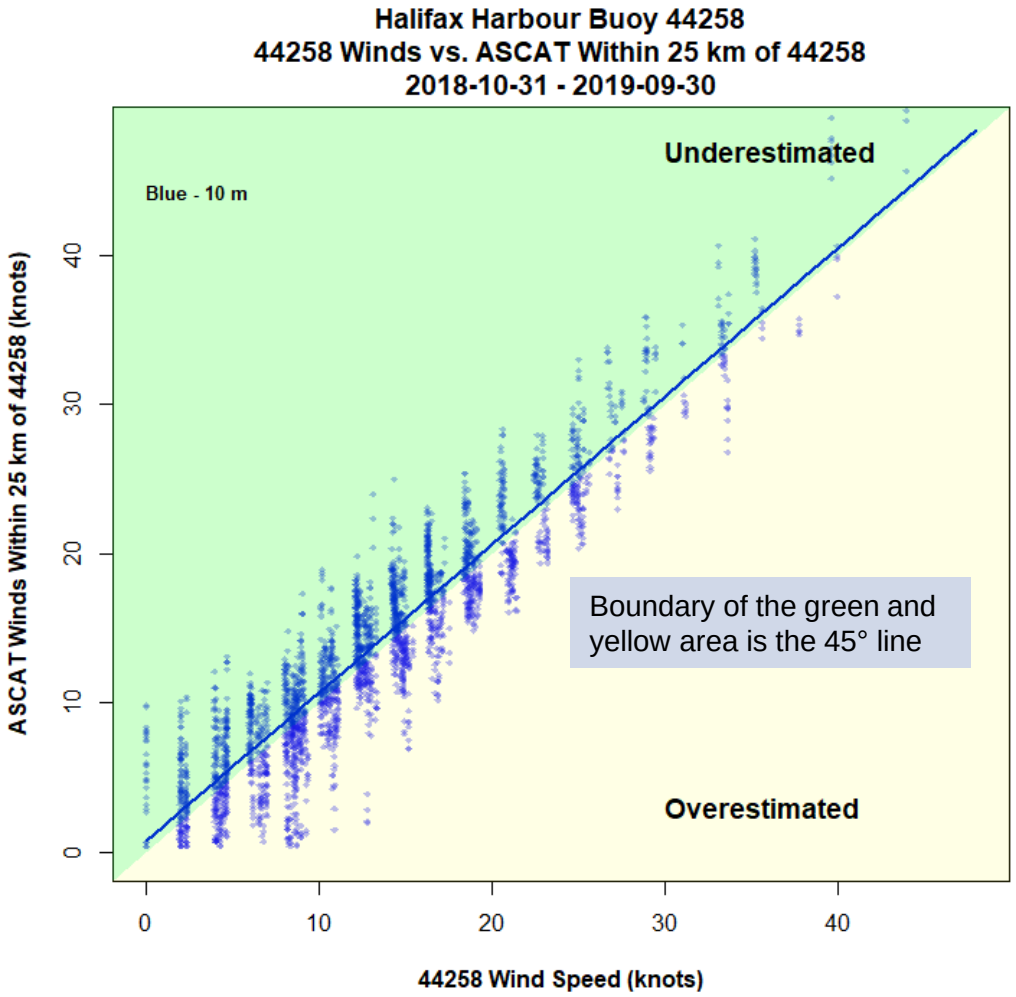
- We consider NOAA ASCAT 12.5-km open-water wind measurements as the reference 10 metre wind field.
- For each observation, obtain all available ASCAT winds taken within ± 30 minutes within a 25 km radius of the observing site (buoy or coastal station).
- Data observed between October 2018 and September 2019 are used.

AN EXAMPLE OF THE RESULTING REGRESSION PLOTS



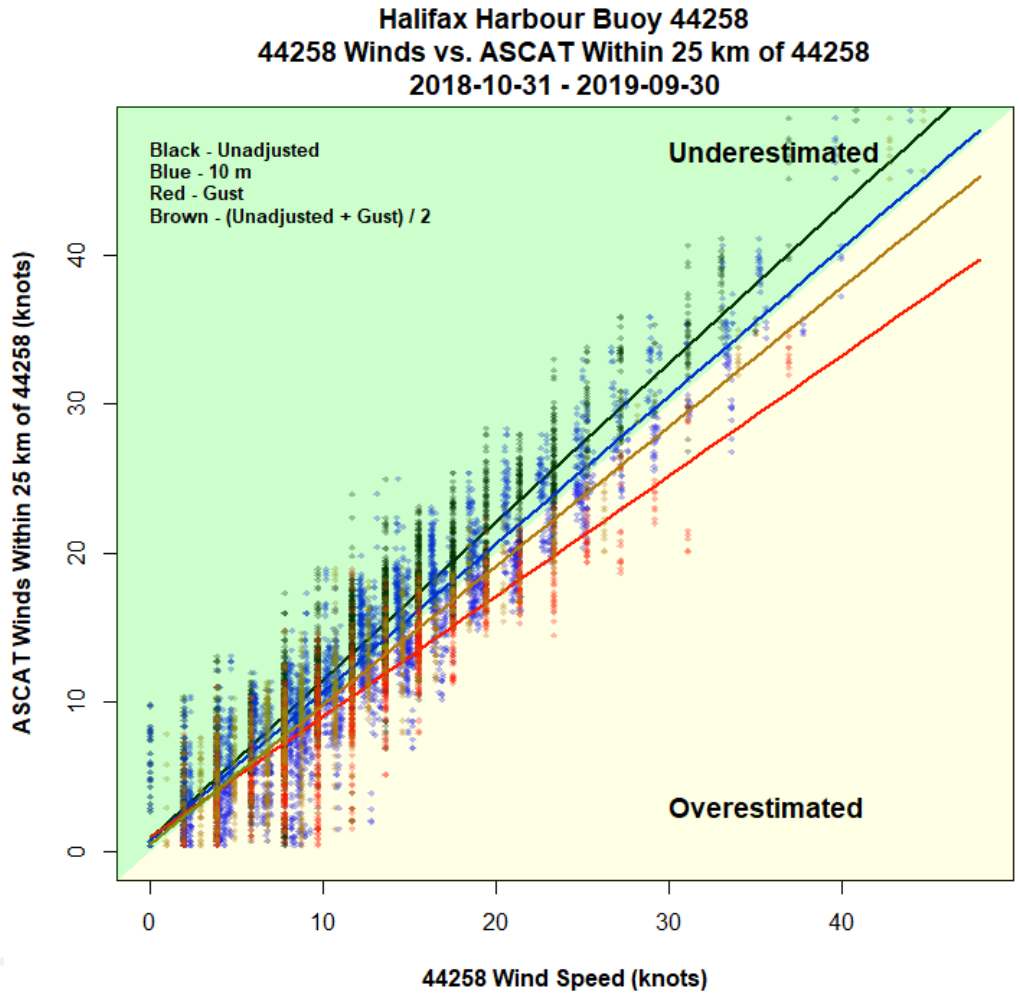
- Winds from the surface observing platform are corrected to 10 m and ASCAT observations within 25 km are plotted.
- Corresponding linear regression line and box plots are also shown.

AN EXAMPLE OF THE RESULTING REGRESSION PLOTS



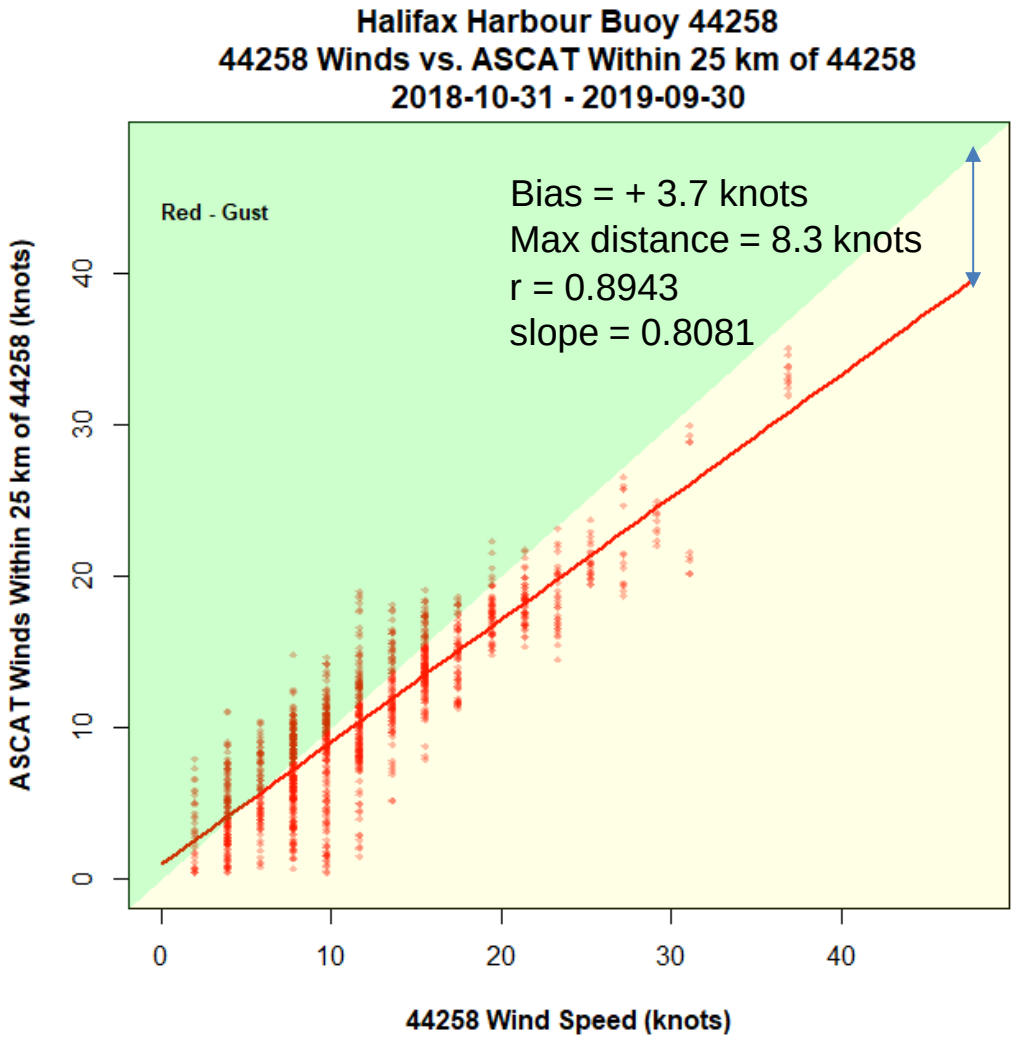
- An observed value under-estimating the ASCAT winds will result in the sample point plotted in the green area.
- The opposite situation will result in the point lying in the yellow area.
- If sample points are generally found along the 45° line with little scatter (correlation coefficient → 1), the station is considered to be representative of the open water winds nearby.

AN EXAMPLE OF THE RESULTING REGRESSION PLOTS



- For the Halifax Harbour Buoy, **winds corrected to 10 m** appear to be the most representative of the conditions nearby.
- The **unadjusted winds** tend to under-estimate the true wind field, while the **gusts** tend to over-estimate. The **mean between the unadjusted wind and the gust** also over-estimates.
- This is the expected behavior for buoys.

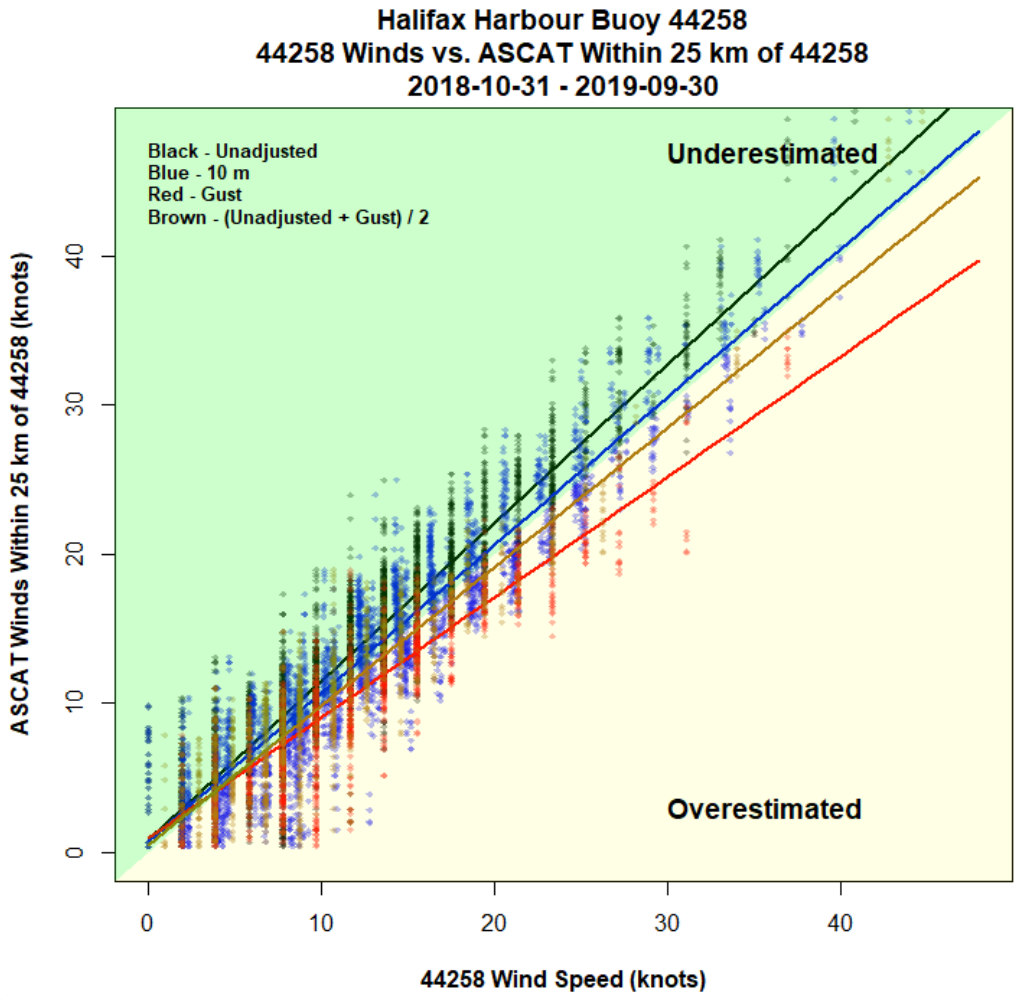
QUANTIFYING THE “CLOSENESS” TO THE 45° LINE



Parameters considered:

- Bias: mean of distances to the 45° line at both ends of the regression line;
- Absolute error: maximum distance from the regression line to the 45° line;
- Sample points dispersion: correlation coefficient (r);
- Slope of the regression line.

QUANTIFYING THE “CLOSENESS” TO THE 45° LINE



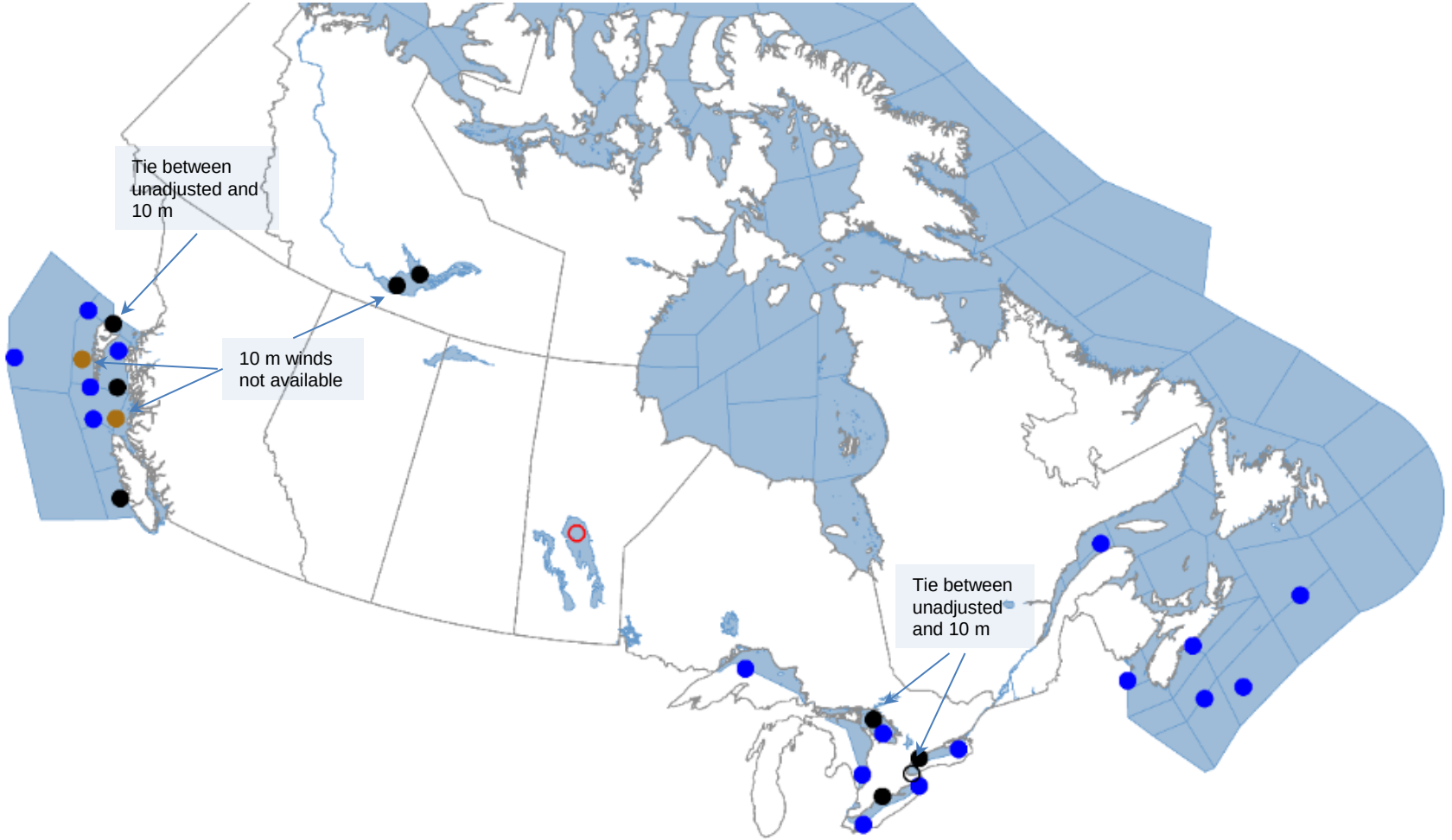
- A scoring scheme* is developed using the aforementioned parameters.
- The score ranges from 0 (poor fit) to 6 (best fit).

Results for the Halifax Harbour Buoy 44258

Data Set	Score
10 m winds	6
Unadjusted winds	2
Mean of unadjusted and gust	2
Gusts	1

* Please see appendix for R code

RESULTS FOR BUOYS



Good Agreement with ASCAT Winds (Score ≥ 4)

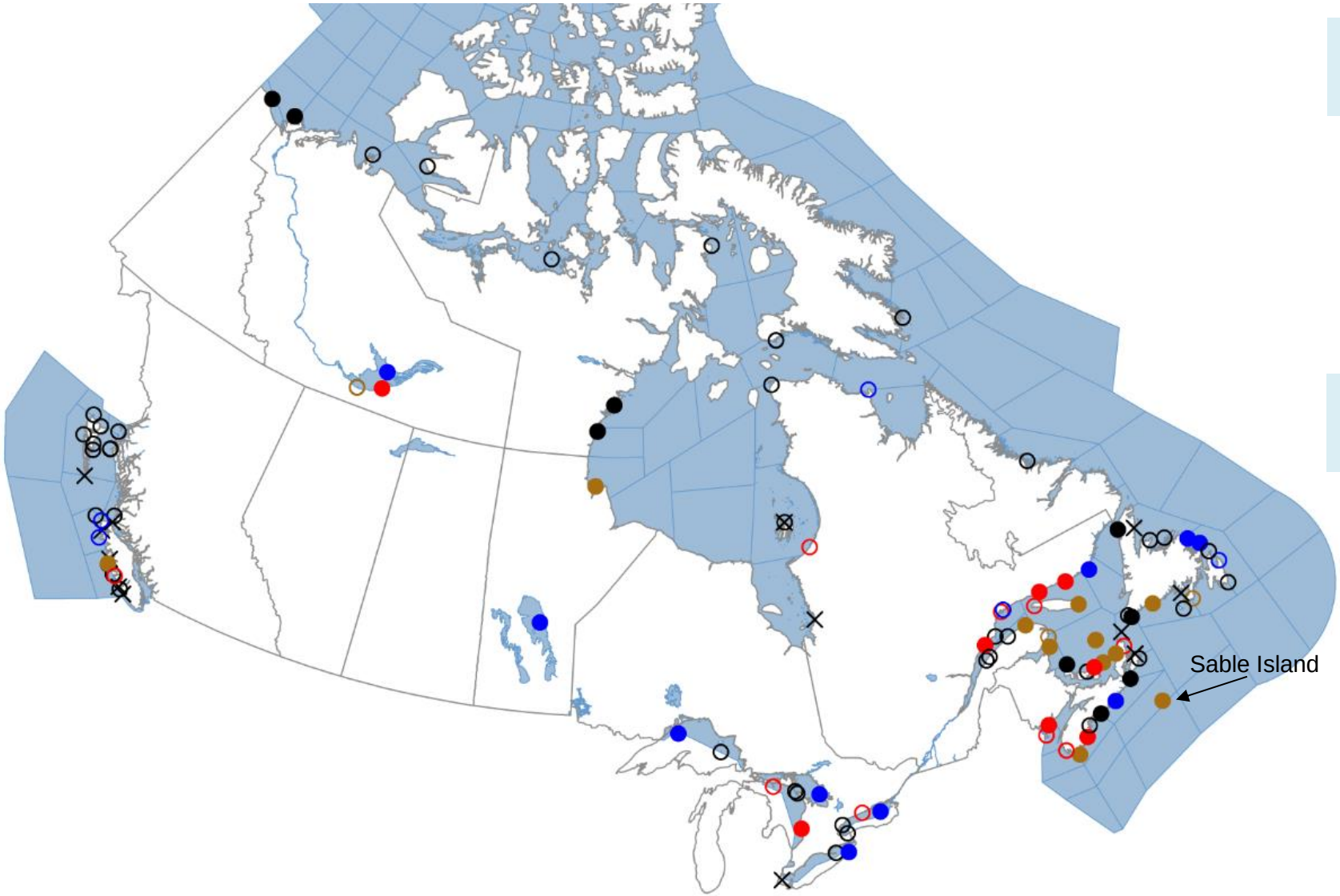
- Unadjusted
- 10 m
- Gust
- Mean of unadjusted & gust

Marginal Agreement with ASCAT Winds (1 ≤ Score ≤ 3)

- Unadjusted
- 10 m
- Gust
- Mean of unadjusted & gust

- Not recommended for use (Score = 0)

RESULTS FOR COASTAL STATIONS



Good Agreement with ASCAT Winds (Score ≥ 4)

- Unadjusted
- 10 m
- Gust
- Mean of unadjusted & gust

Marginal Agreement with ASCAT Winds (1 ≤ Score ≤ 3)

- Unadjusted
- 10 m
- Gust
- Mean of unadjusted & gust

- Not recommended for use (Score = 0)

TAKEAWAYS FROM THE ANALYSIS

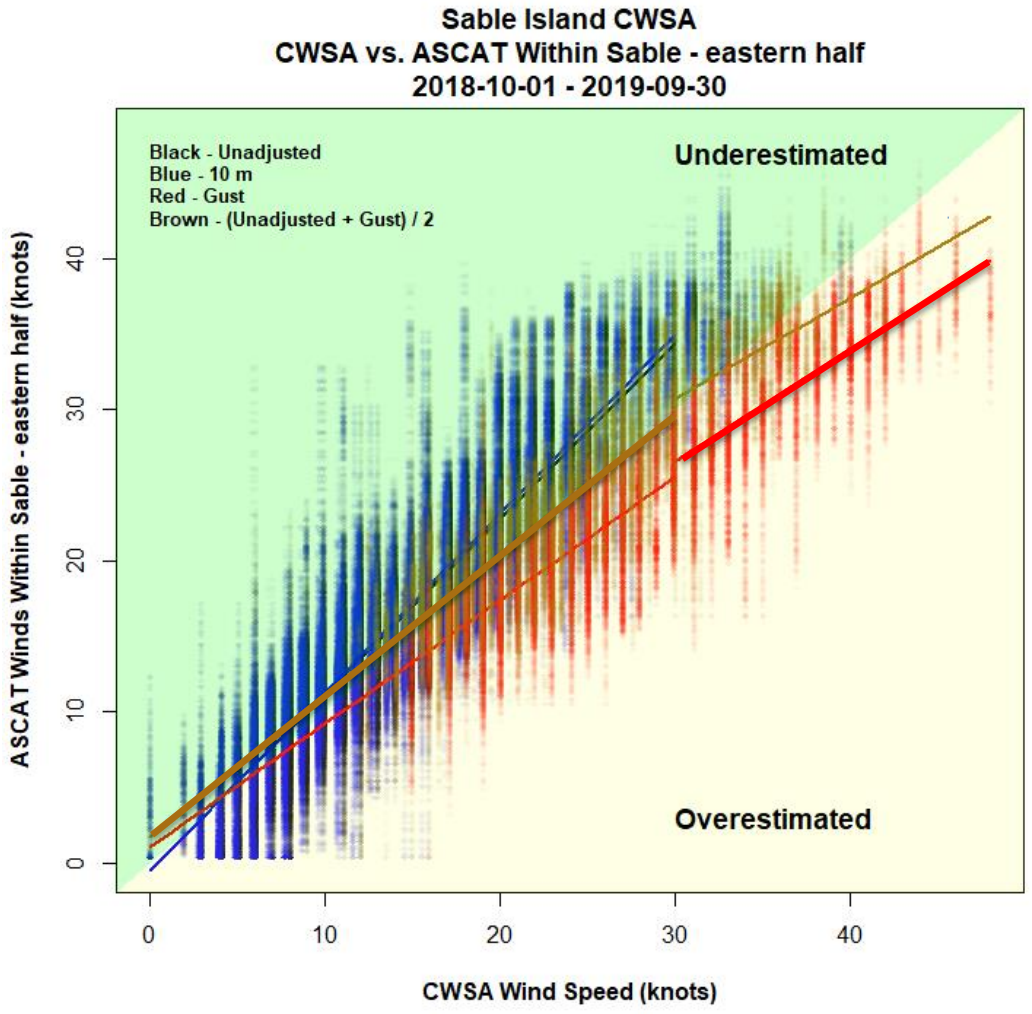
- The “one size fits all” approach of correcting all land winds to 10 metres does not work well.
- Gusts or estimates from forecaster rules of thumb may reflect the open water winds better than the reported sustained winds.
- A new approach that takes these factors into account has been developed to estimate open water winds.

NEW APPROACH FOR HANDLING OBSERVATIONS

- For each observing station, forecasters were consulted to determine whether its *unadjusted sustained speeds*, *10 m speeds*, *gusts*, or *the mean values of the unadjusted speed & gust* should be used for verification purposes.
- To account for instrument bias at higher wind speeds, it is possible to use different datasets to verify the < 30 knots range and the ≥ 30 knots range.
- Results from regression analyses similar to those presented earlier are provided to forecasters to help them choose the most representative datasets.

Observed Values < 30 knots	Observed Values >= 30 knots
❑ Unadjusted Sustained Speed	❑ Unadjusted Sustained Speed
❑ 10 m Speed	❑ 10 m Speed
❑ Gust	☑ Gust
☑ Mean of Unadjusted Speed and Gust	❑ Mean of Unadjusted Speed and Gust

NEW APPROACH FOR HANDLING OBSERVATIONS



- In this example, forecasters agree that for the < 30 knots range, **mean values of the unadjusted wind and gust** from Sable Island best represent open water winds.
- For the ≥ 30 knots range, **gusts** are chosen as the more representative data set.
- The systematic positive bias of the gusts is corrected using results of the corresponding regression analysis.

Note: For verification of forecasts over a region (polygon), surface observations were compared to ASCAT winds collected over the entire polygon, instead of a 25-km circle.

CONCLUSIONS

- In most cases, buoy wind speeds corrected to 10 metres agree well with ASCAT-derived measurements of the nearby wind field.

- However, winds observed at coastal stations do not behave the same way, even for those that are well-exposed to the marine environment.

- For the purpose of marine verification, the “one size fits all” approach of using observed winds reported by coastal stations, or winds corrected to 10 metres above water level, is not recommended.

- Motivated by this discovery, a new approach is proposed, based on regression analyses, leveraging the local knowledge of forecasters to identify the most representative dataset for each coastal station. Where it makes sense to do so, the results of the regression analyses are also used to correct systematic biases of the observations.

NEXT STEPS

- The regression analyses presented are based on the October 2018 to September 2019 dataset. Limited stratification is performed to avoid the problem of small sample sizes.

- With two full years of data we plan to refine the analyses using stratified datasets (e.g. by stability class, wind direction, etc.).

- Results from the re-analyses will also help operational forecasters interpret marine wind observations.

ACKNOWLEDGEMENTS

- Dr. Barbara Casati – Research Scientist, Atmospheric Numerical Weather Prediction Research
- Members of the Prediction Verification Working Group – Prediction Services Directorate

QUESTIONS?

APPENDIX – SCORING SCHEME FOR QUANTIFYING THE “CLOSENESS” TO THE 45° LINE

```
getFitQualifiers <- function(xVect, yVect, slope, corCoef) {
  xLeft <- xVect[1]
  xRght <- xVect[length(xVect)]
  yLeft <- yVect[1]
  yRght <- yVect[length(yVect)]
  errLeft <- xLeft - yLeft
  errRght <- xRght - yRght
  #print(sprintf("errLeft=%s errRight=%s Slope=%s CorCoef=%s", errLeft, errRght, slope, corCoef))
  maxAbsErr <- max(abs(errLeft),abs(errRght))
  bias <- (errLeft + errRght) / 2

  accuracyQual <- NA
  accuracyThresDf <- data.frame(LeftBnd=c(0,2,4),RightBnd=c(2,4,9999),Qualifier=c("Good","Acceptable","Poor"))
  accuracyQual <- accuracyThresDf$Qualifier[maxAbsErr >= accuracyThresDf$LeftBnd & maxAbsErr < accuracyThresDf$RightBnd]
  if ( accuracyQual=='Poor' && corCoef >= 0.69 ) { accuracyQual <- 'Marginal' }

  biasQual <- NA
  biasThresDf <- data.frame(LeftBnd=c(-9999,-1,1),RightBnd=c(-1,1,9999),Qualifier=c("Underestimated","Neutral","Overestimated"))
  biasQual <- biasThresDf$Qualifier[bias >= biasThresDf$LeftBnd & bias < biasThresDf$RightBnd]

  scoreComposite <- 0
  if ( is.na(accuracyQual) ) {
    scoreComposite <- 0
  } else if ( accuracyQual == 'Good' ) {
    scoreComposite <- scoreComposite + 3
  } else if ( accuracyQual == 'Acceptable' ) {
    scoreComposite <- scoreComposite + 2
  } else if ( accuracyQual == 'Marginal' ) {
    scoreComposite <- scoreComposite + 1
  }

  if ( grepl('Marginal|Poor',accuracyQual) && errLeft*errRght < -accuracyThresDf$LeftBnd[accuracyThresDf$Qualifier=='Poor']^3 ) { biasQual <- NA }
  if ( is.na(slope) || (!is.na(slope) && slope < 0.5) || (!is.na(slope) && slope > 2)) { biasQual <- NA }

  if ( is.na(biasQual) ) {
    scoreComposite <- 0
  } else if ( biasQual == 'Neutral' && !grepl('Marginal|Poor',accuracyQual) ) {
    scoreComposite <- scoreComposite + 3
  }
  return(list(ErrLeft=errLeft, ErrRght=errRght, MaxAbsErr=maxAbsErr, Bias=bias, AccuracyQual=accuracyQual, BiasQual=biasQual, ScoreComp=scoreComposite))
}
```

xVect – site wind samples
yVect – ASCAT wind samples
Slope – slope of regression line
corCoef – correlation coefficient