A Study of Bias and Inhomogeneity in Wind Speeds from Moored Buoys

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Environment Canada

CLIMAR III, 6-9 May 2008

Introduction (1)

- We investigate two changes in buoy wind measurement methods that have the potential to introduce inhomogeneities in the long term record:
  - a change in the 1980s and 1990s from vector to scalar mean averaging
  - More recently, in addition to the propeller-vane anemometer, there has been increased use of sonic anemometer (usually in the second or back-up position)
- Using large datasets we develop relationships between vector and scalar means, and between propeller-vane and sonic anemometer winds, which can be used to adjust the data series

Introduction (2)

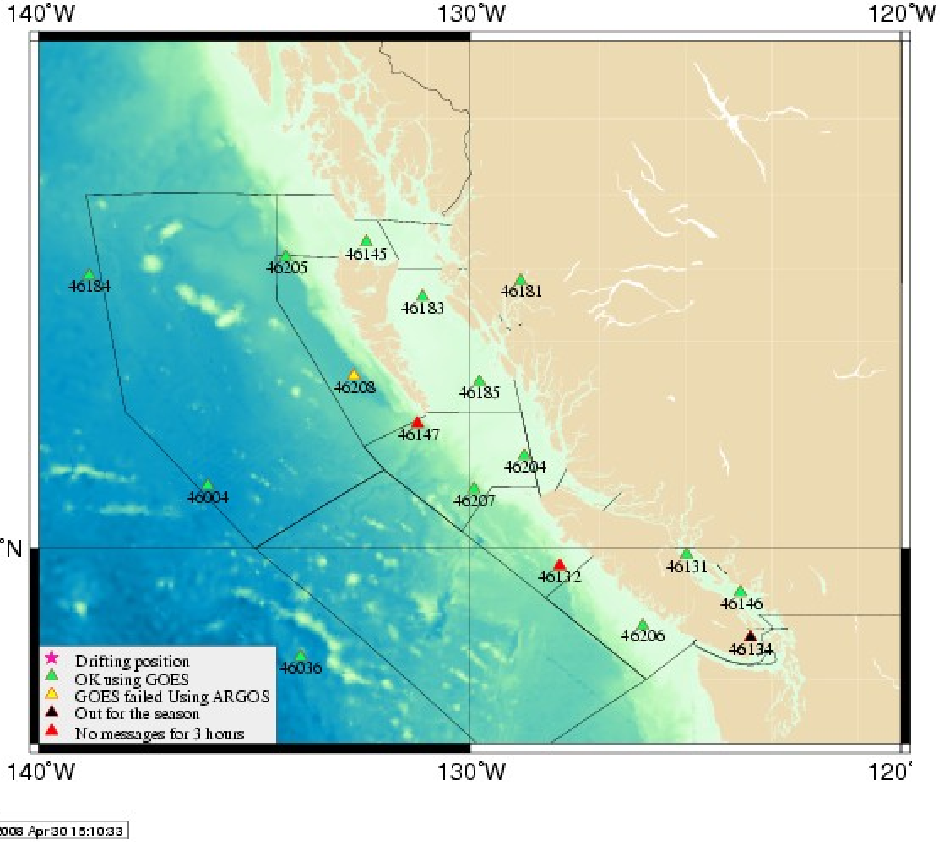
- We examine the impact of measurement changes on long-time series wind data (including anemometer height) and we assess the effect of adjusting for these changes
- other program changes over time include the size and type of platform and the processing software (part of the buoy payload)
- We explore use of a statistical program called RHTest, designed to detect undocumented mean shifts in climate data series (Wang, Wen, and Wu 2007)

Anemometer Types

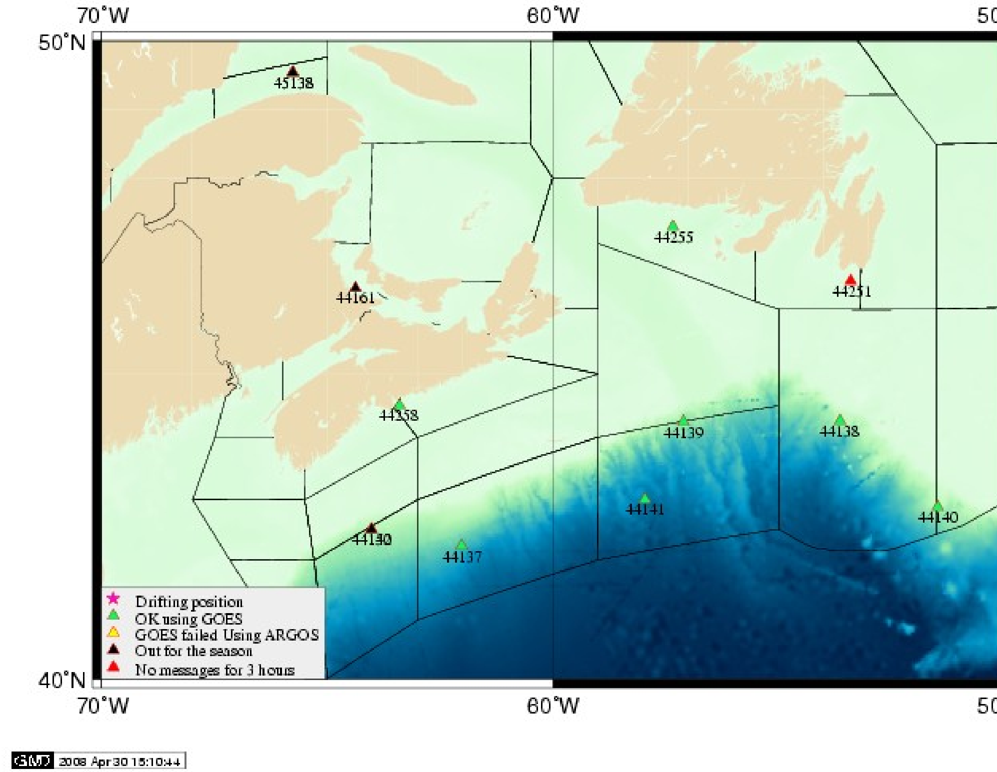
- propeller vane
- ultrasonic

Buoy Platform Types

Pacific Moored Buoys



Atlantic Moored Buoys



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Data Sources

- Fisheries and Oceans Canada’s ISDM (formerly MEDS) for Environment Canada (EC) raw buoy data
- NODC for F291 format NDBC buoy data (includes anemometer ht)
- NDBC for metadata on NDBC buoys, e.g.
  - www.ndbc.gov/ www.ndbc.gov/data_availability/data_avail.php?station=46004
- EC buoy metadata from status reports and personal communication, MSC Buoy Specialists Vaughn Williams and Randy Sheppard

Vector Scalar Comparisons

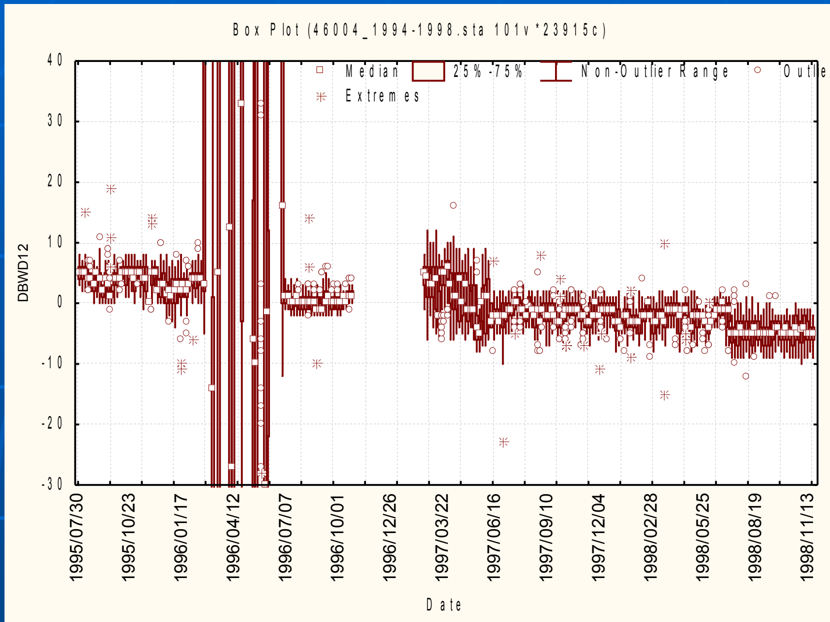
- We analyzed a large dataset of vector and scalar means from the same anemometer on most Environment Canada’s ocean buoys, 1994-1999

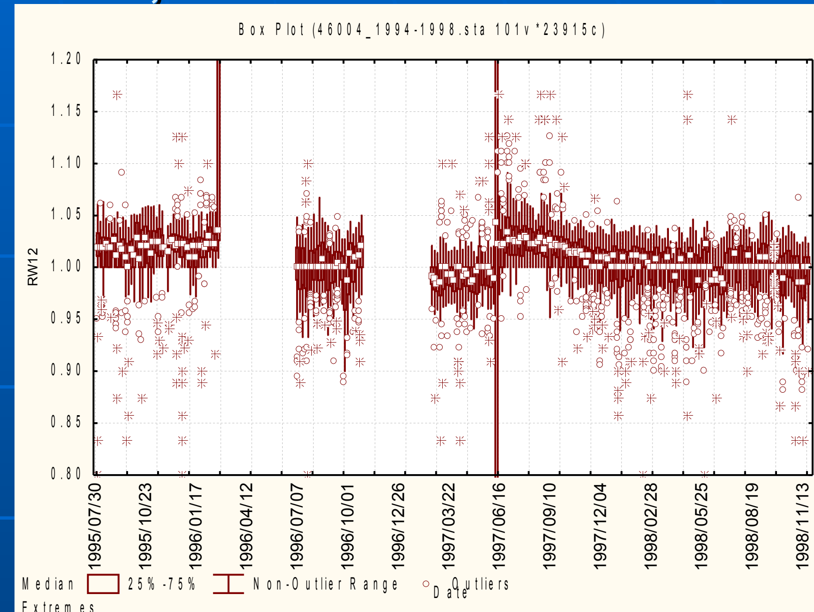
[We also analyzed a small dataset from 2 co-located NDBC buoys]

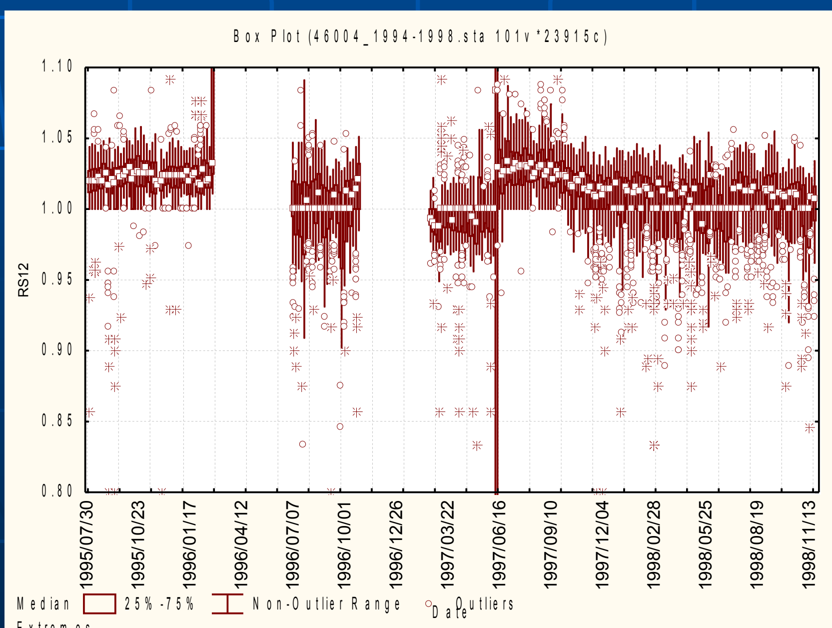
Vector Scalar Comparison – Environment Canada buoys

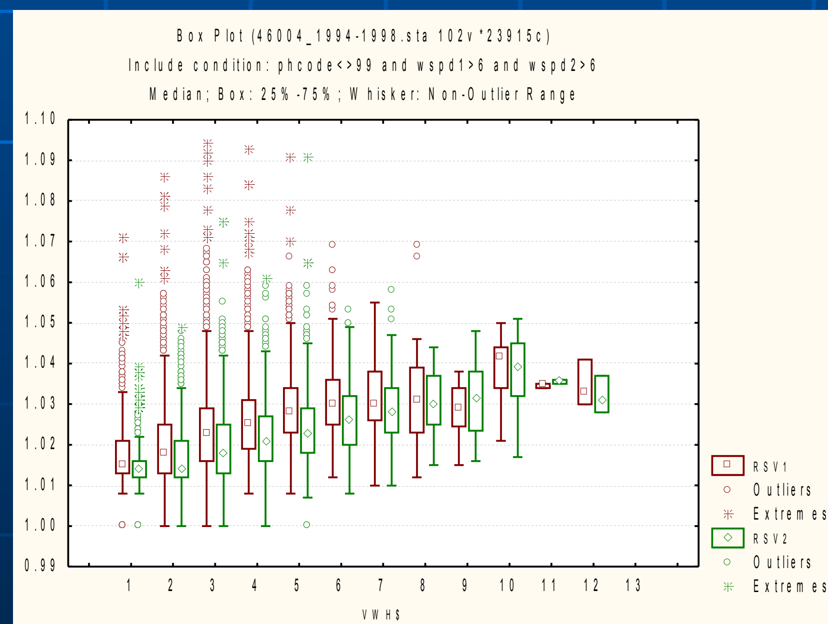
- For about 5 years most EC buoys made hourly reports of both the vector and scalar mean wind speed for each anemometer (RM Young propeller-vane type, Zeno payload)
- Large dataset: hourly obs from three NOMAD and twelve 3D buoys on the west coast of Canada (from 18 000 – 50 000 observations at each buoy) and from six NOMAD buoys on the east coast (with only about 2000 obs from each)
- peak significant wave heights reach 9 to 15 m at all but 2 of the buoys

Wind Quality Diagnostics
for Middle Nomad 46004, 1995-1998

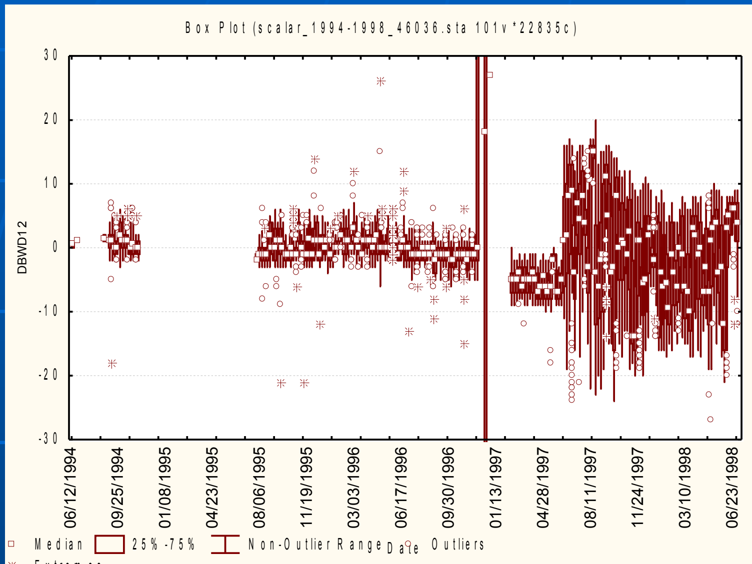


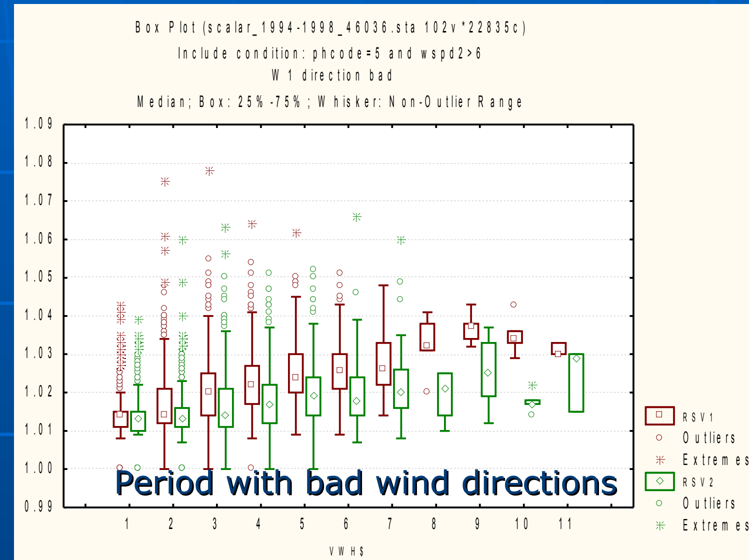


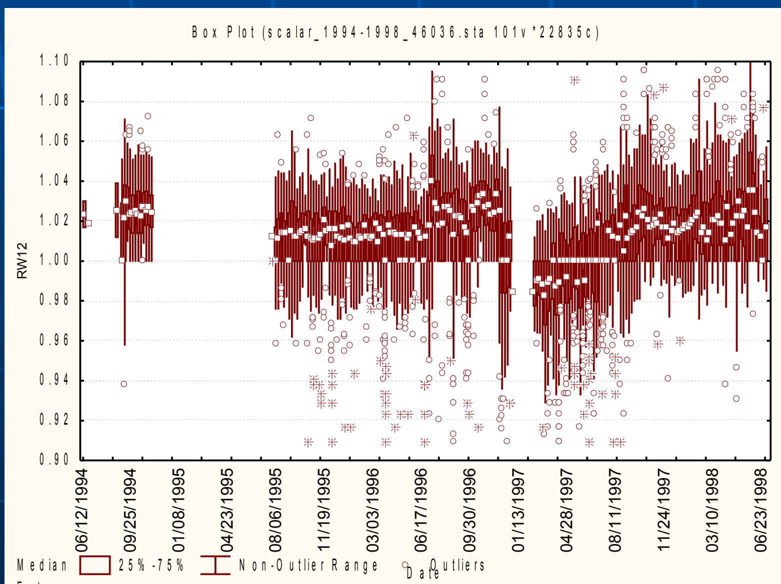


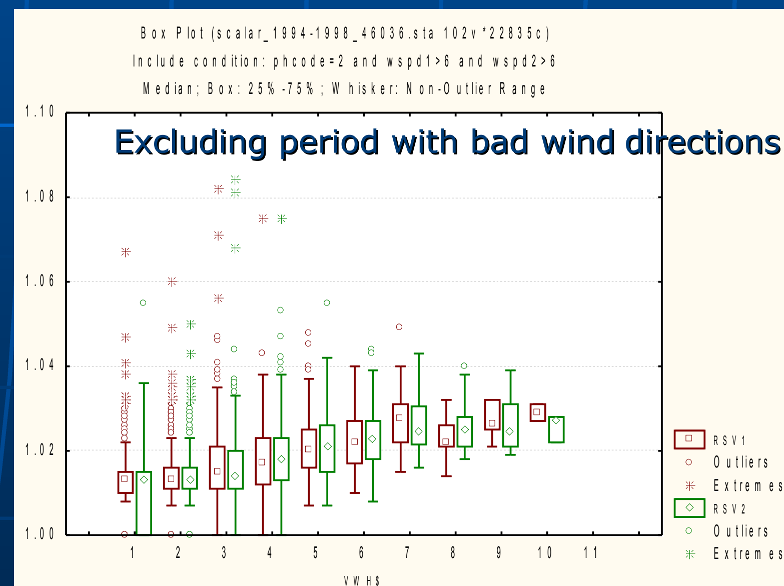


Wind Quality Diagnostics for South Nomad 46036, 1994-1998

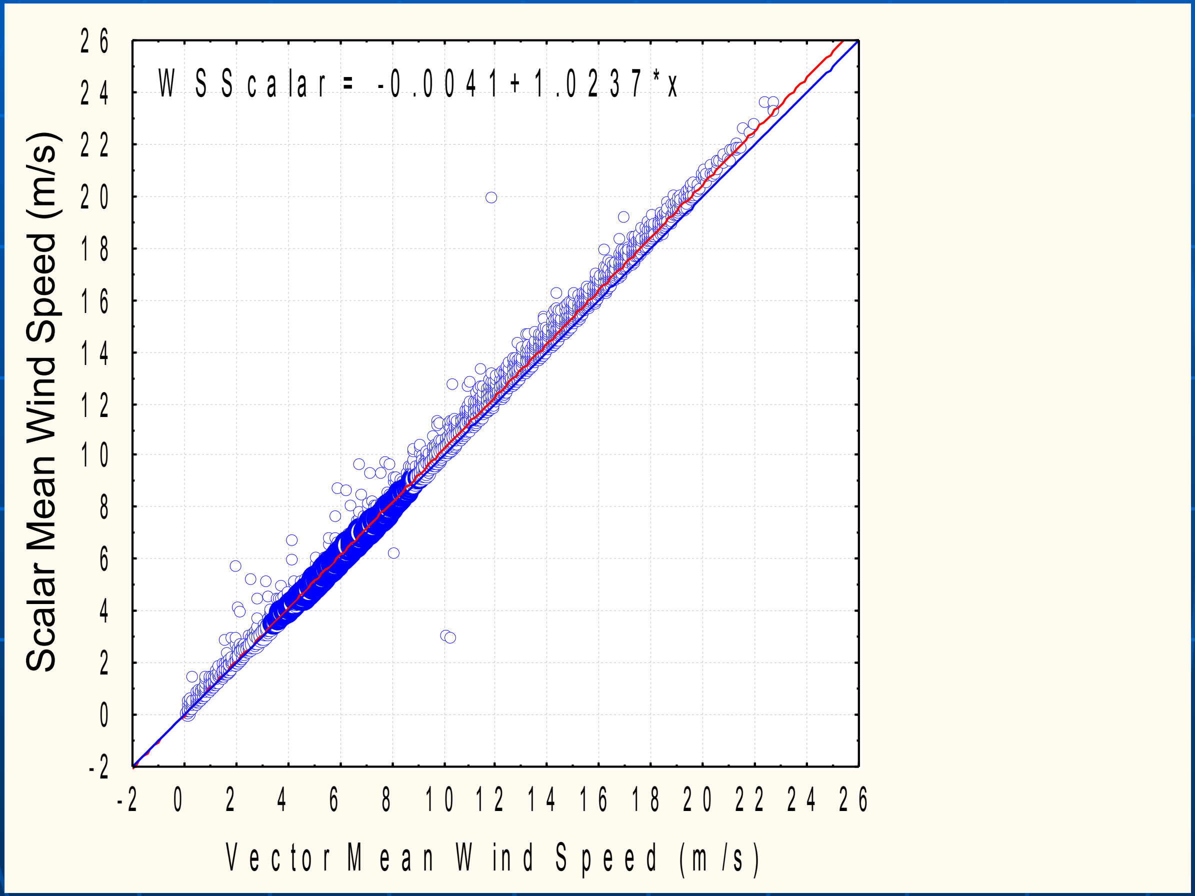






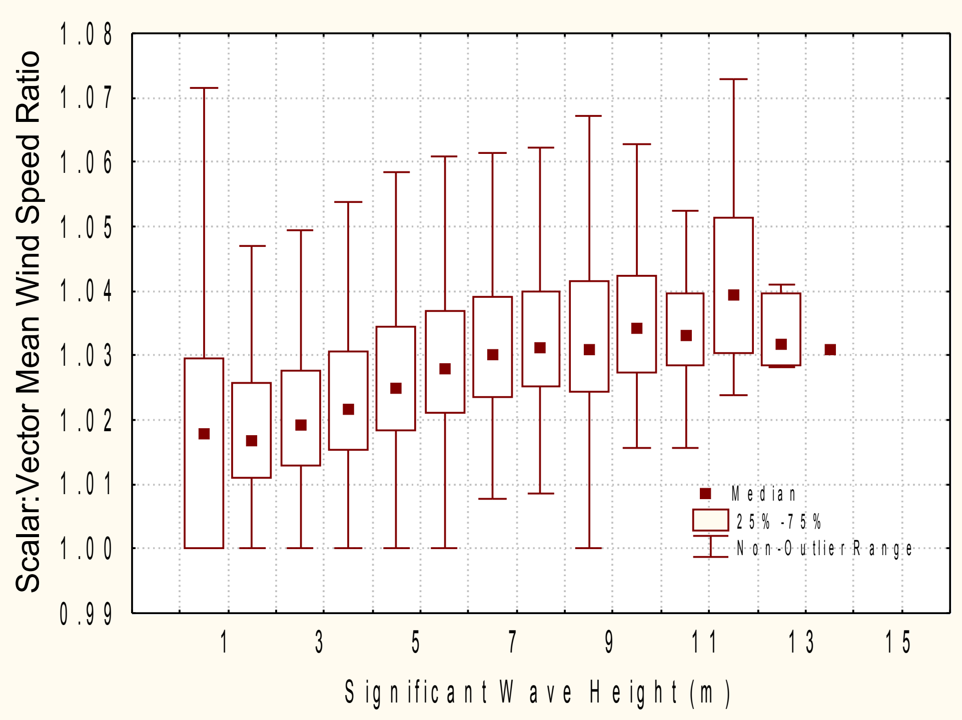


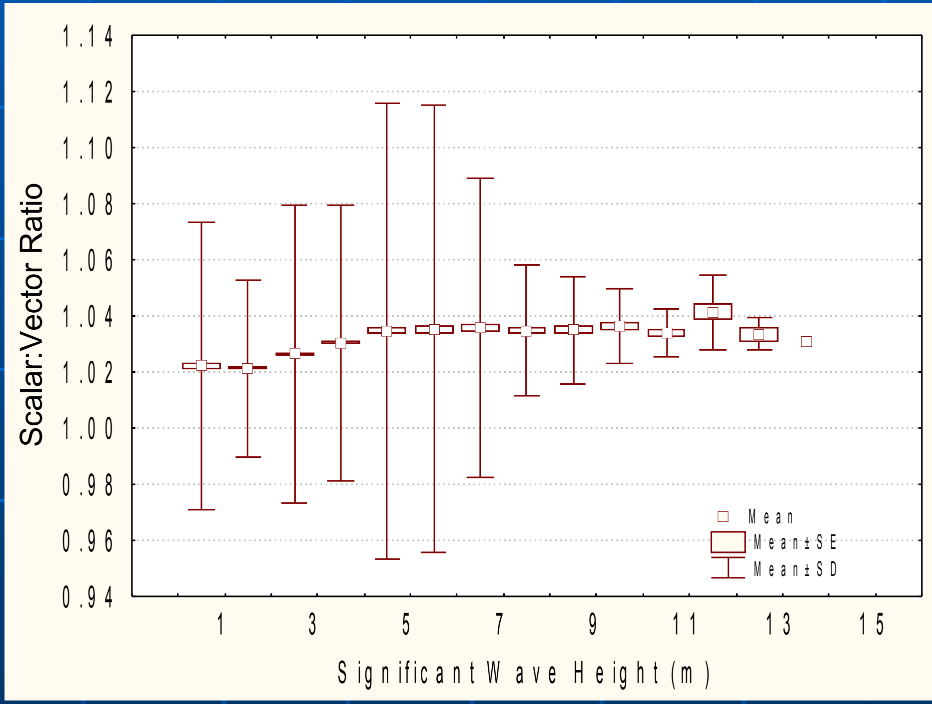
Relationship between Scalar & Vector Mean Wind Speeds, west coast NOMADs



- Scalar winds about 2% greater than vector (3 west coast NOMADs combined, N=86 273)
  46184, 46004, 46036

Scalar:Vector Mean Wind Speed Ratio and Wave Height



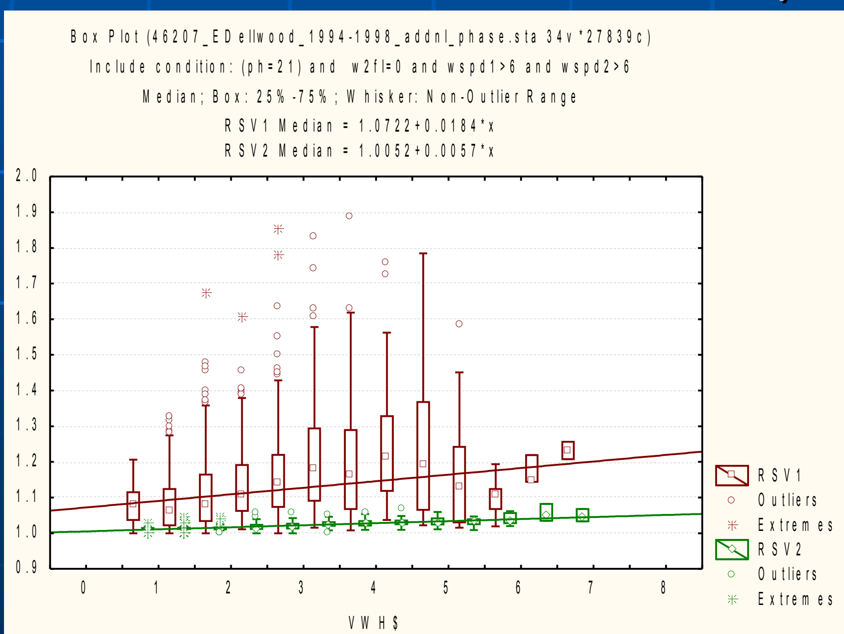


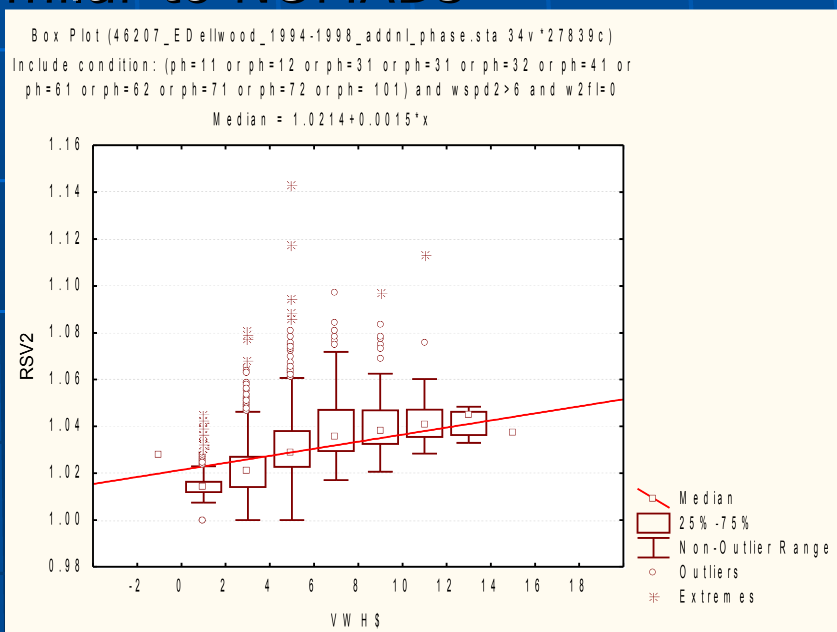
Box plots of scalar:vector ratio binned on wave ht, medians (left) and means (right)

- 3 west coast NOMADs combined, N=86273
  - 46184, 46004, 46036

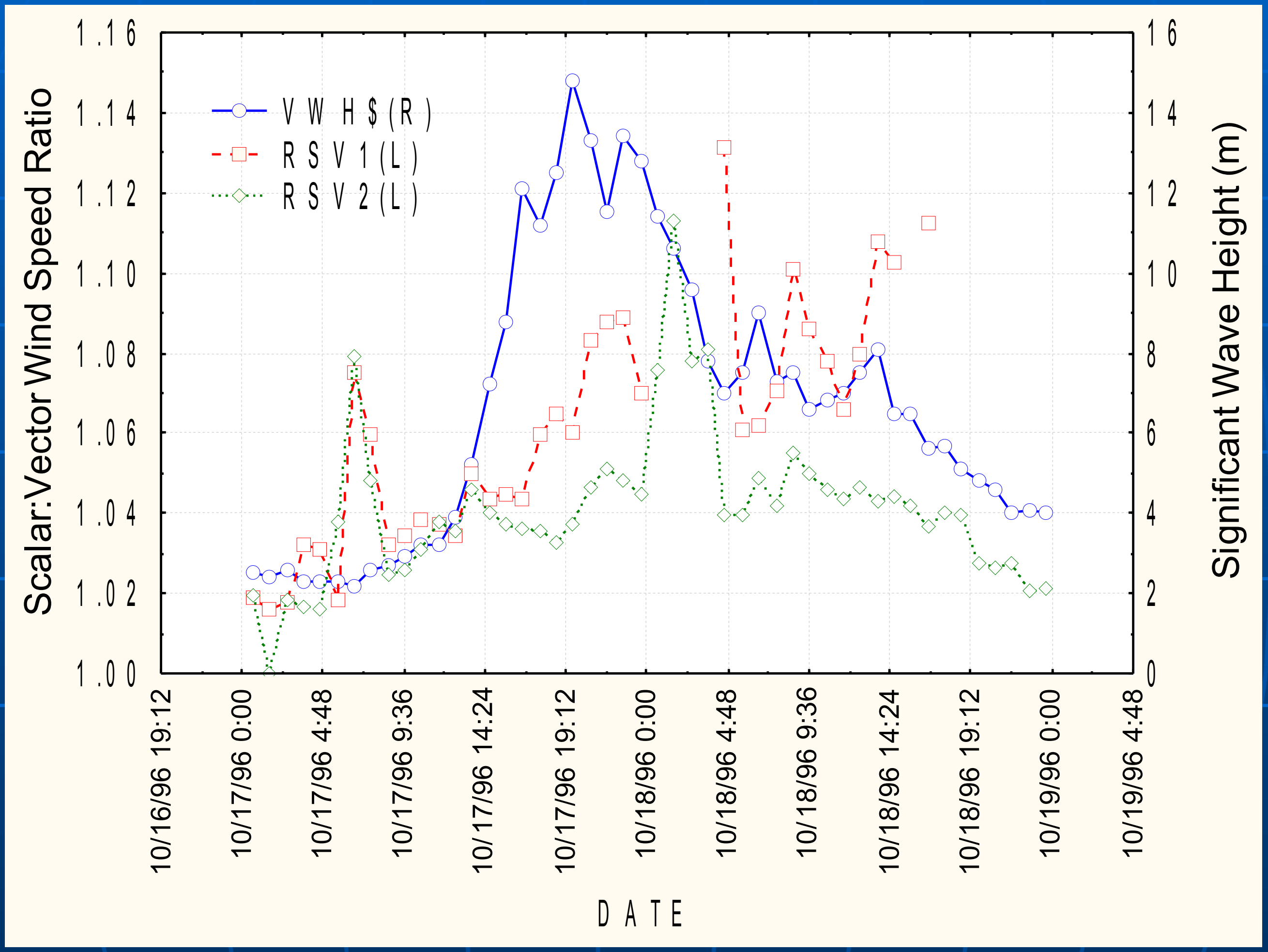
Scalar-vector ratio binned on Hs, at 3D buoy 46207 (for subsets of the full period)

- Left panel shows a period with W1 vector speed reduced, RSV up to 1.20
- Right panel shows all periods with good W1 data, RSV increases with Hs to 1.04, similar to NOMADs



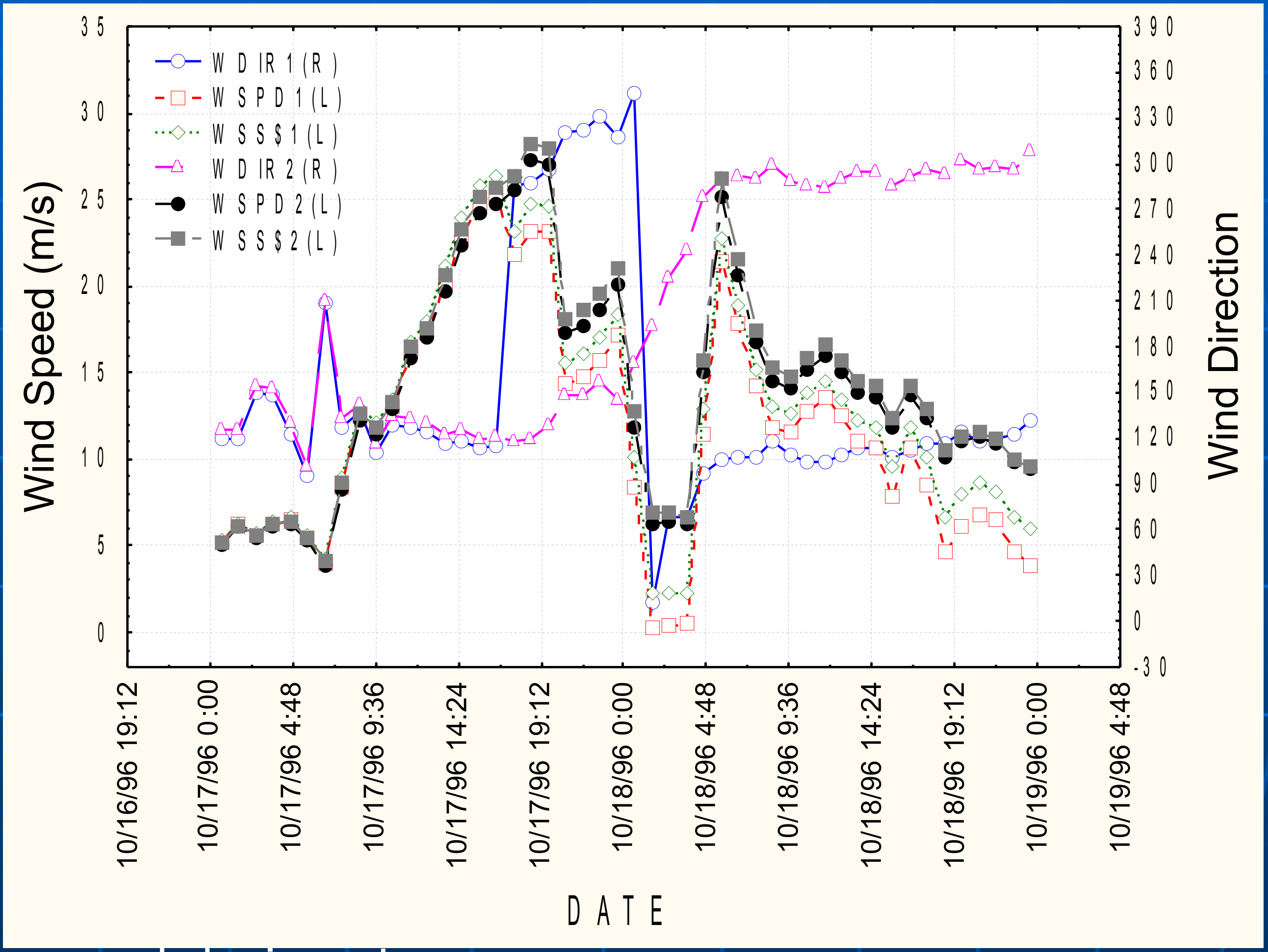


Storm 17-18 Oct 1996, 46207 (3D)
Wave Height and Scalar Vector Ratios (W1 and W2)



- W1 damaged during this storm; peak Hs reached nearly 15 m
- over the 5 winters with both vector & scalar means, one or both anemometers broke in storms each winter

Storm 17-18 Oct 1996, 46207 (3D)
Wind 1 and 2 Directions and Speed



- W1 damaged during storm
  - W1 direction bad
  - W1 winds (vector, scalar, and gust) reading low compared to W2

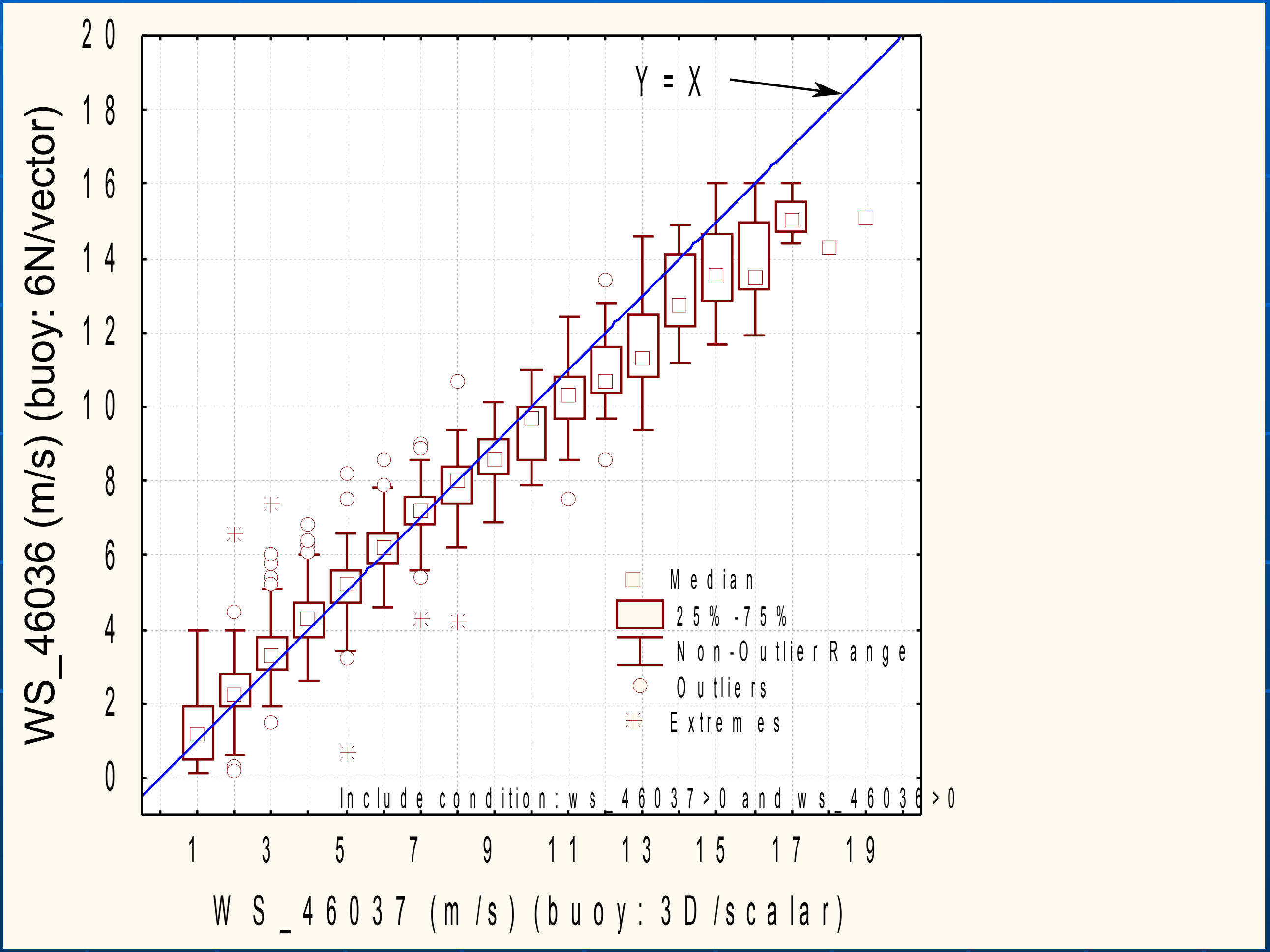
Results of Vector Scalar Comparison – EC buoys

- the median value of the scalar-mean wind speed is about 2% higher than the vector-mean from fully functioning anemometers on both 3D and 6N buoys.
- the median difference increases slightly with increasing wave height to about 4%
- Care is needed, especially for 3D buoys, to exclude periods of time with instrument problems such as faulty compasses giving erroneous directions (which reduce the vector mean)

Vector Scalar Comparison – co-located NDBC buoys (1986-1987)

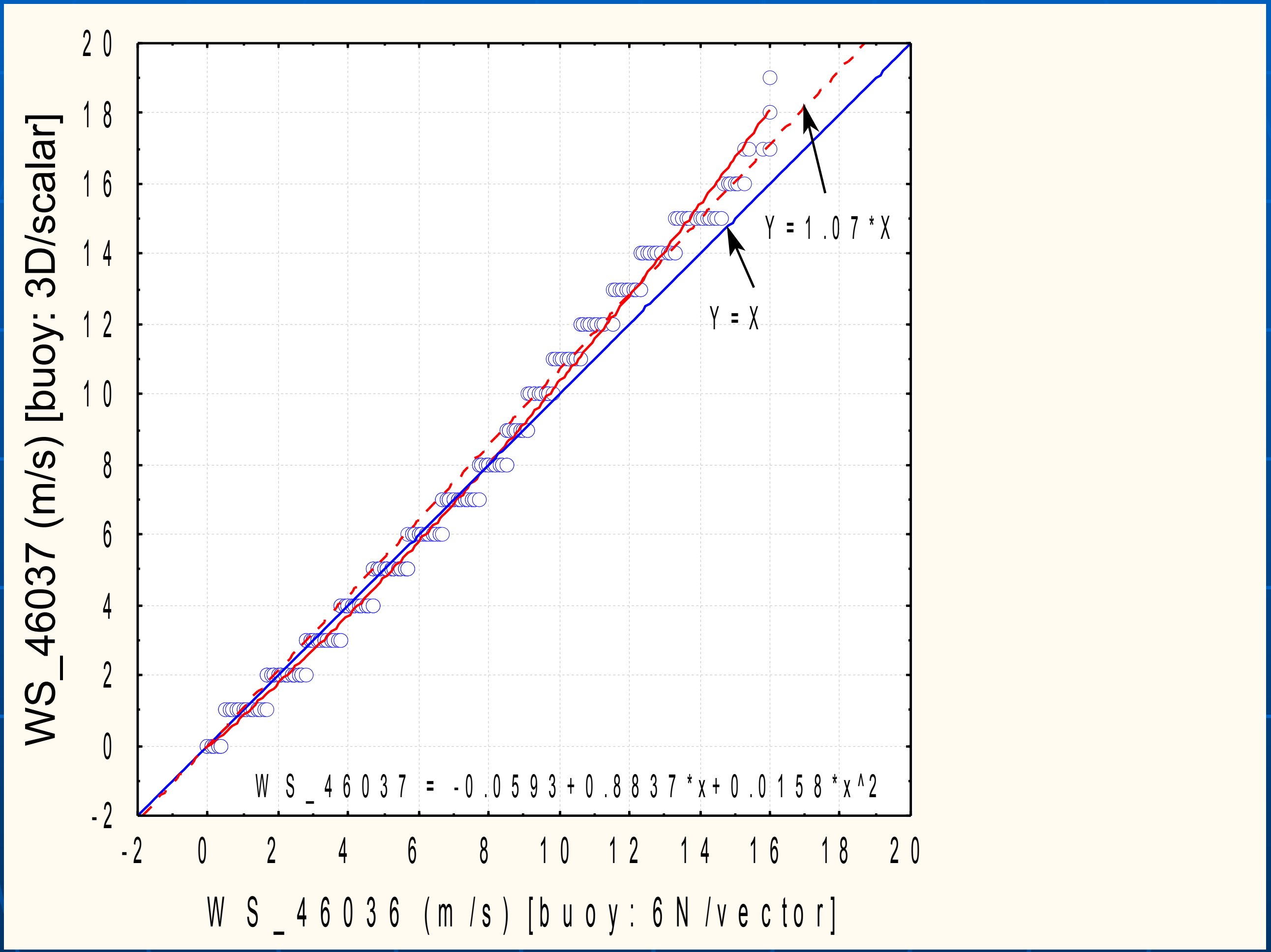
- Gilhousen (1987) analyzed vector and scalar means from the same anemometer on buoy 41001 (a 12D/UDACS(A)) for 03/1984
- the two averaging methods gave the same speed for winds < 8 m/s; for speeds > 8m/s, the vector means were about 7% lower than the scalar means (scalar winds reached 20 m/s)
- We compare a short dataset from 2 NDBC co-located buoys (nominal anemometer height 5 m at both):
  - 6N/GSBP buoy 46036 South Nomad Buoy
    - vector means
  - 3D/DACT buoy 46037
    - scalar means
    - temporarily co-located with 46036, 1986-1987

46036 (vector) winds binned on 46037 (scalar)



- Shows scalar means increasing relative to vector means, for increasing wind speed

Scatterplot: 46037 (scalar) winds vs 46036 (vector) winds



- see that scalar winds are about 7% > vector means, although relationship not linear

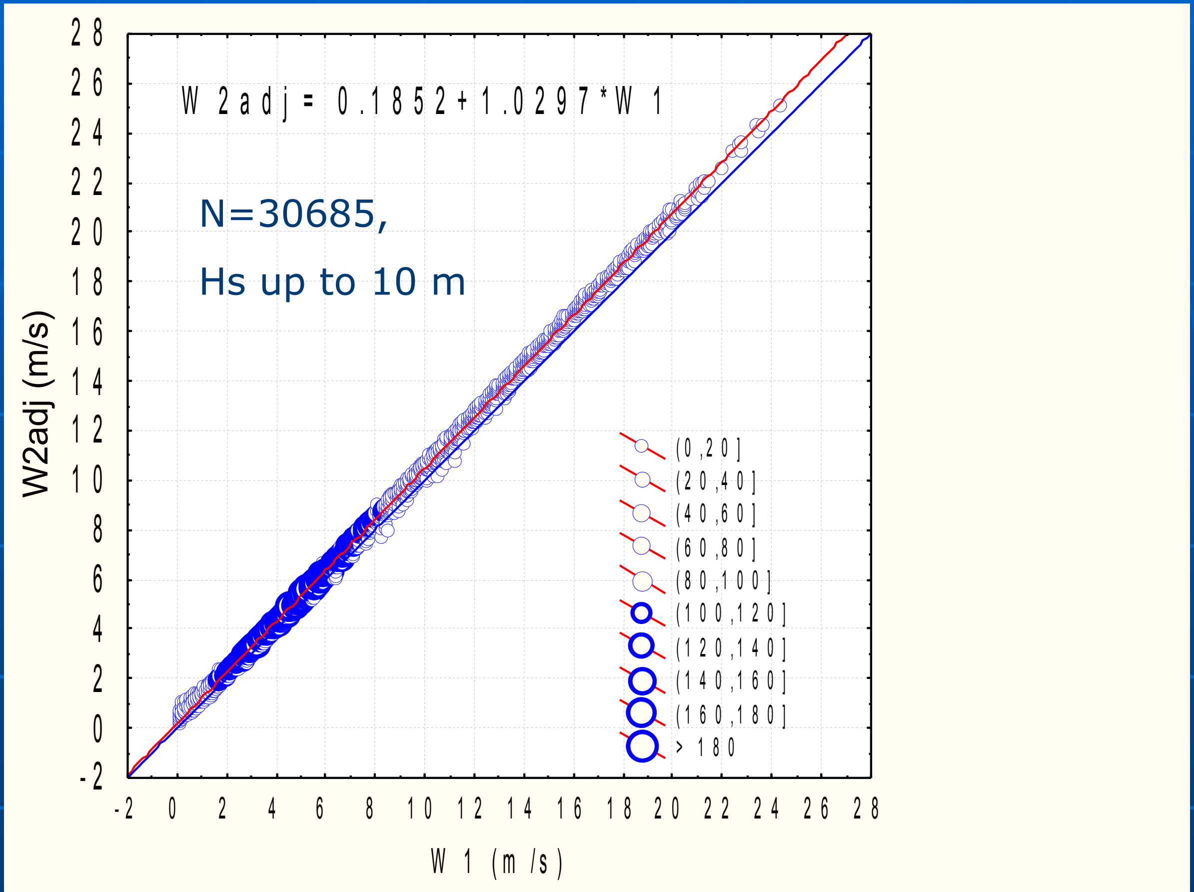
Results from Vector Scalar Comparison – co-located NDBC buoys

- 46037 data archived to only to nearest 1 m/s (46036 to 0.1 m/s)
- the NDBC data show a greater vector scalar difference (than EC buoys), of about 7% - similar to results presented by Gilhousen (1987)
- No explanation for difference between EC and NDBC results – perhaps related to different anemometer?

Propeller-vane and Ultrasonic Anemometer Comparison

- We investigate differences in winds from RM Young propeller-vane anemometers and sonic anemometers installed on the same buoy
- use 8 months of hourly data (May – Dec 2005) from six 3D buoys on the west coast
- All winds are scalar means
- We adjust for the small difference in height (3D buoy RMY anemometer position 1: ht 4.7 m, sonic anemometer position 2: 3.8 m)

Ultrasonic (ht adj) vs RMYoung Wind Speeds

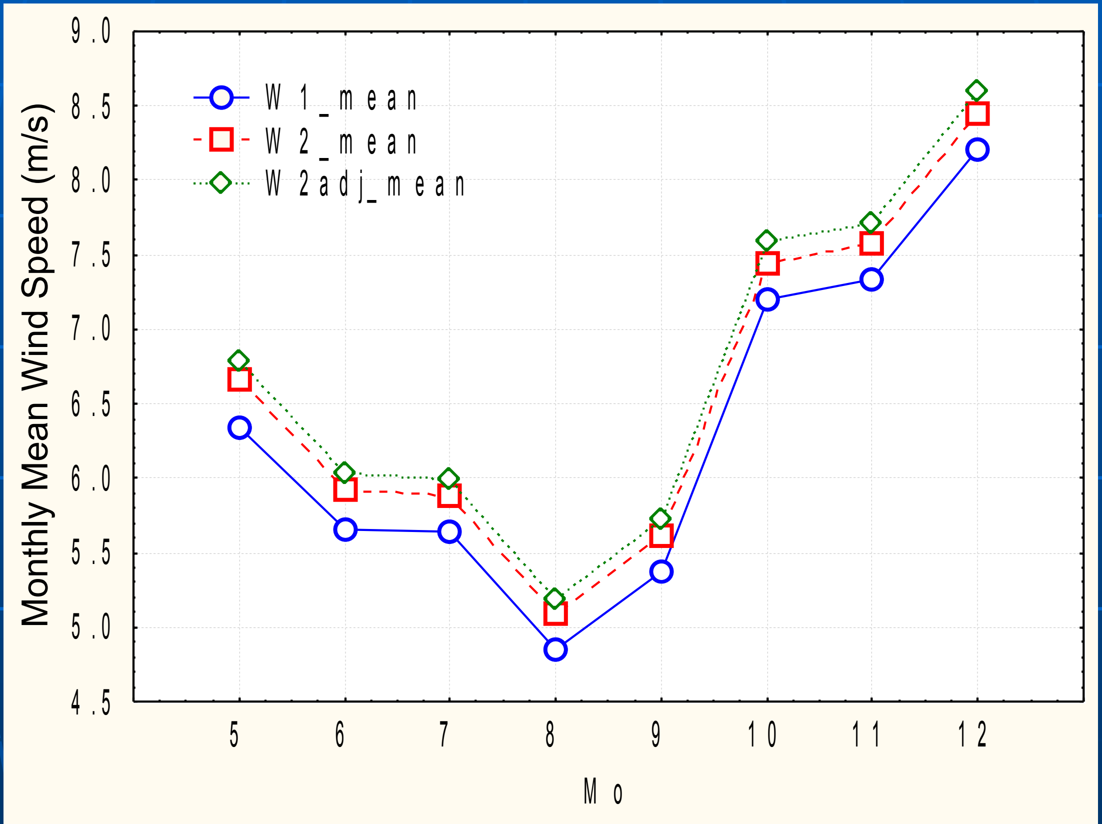


- Ultrasonic vs RMY:

  W2 = 0.18 + 1.011*W1
- Ultrasonic vs RMY, Ultrasonic adjusted to same ht as RMY:

  W2adj = 0.19 + 1.030*W1

Monthly Mean Wind Speeds of RMY and Ultrasonic



- W1: RMYoung winds in position 1 (measured at 4.7 m)
- W2: Ultrasonic winds in position 2 (measured at 3.8 m)
- W2adj: adjusted to same height as RMYoung winds in position 1

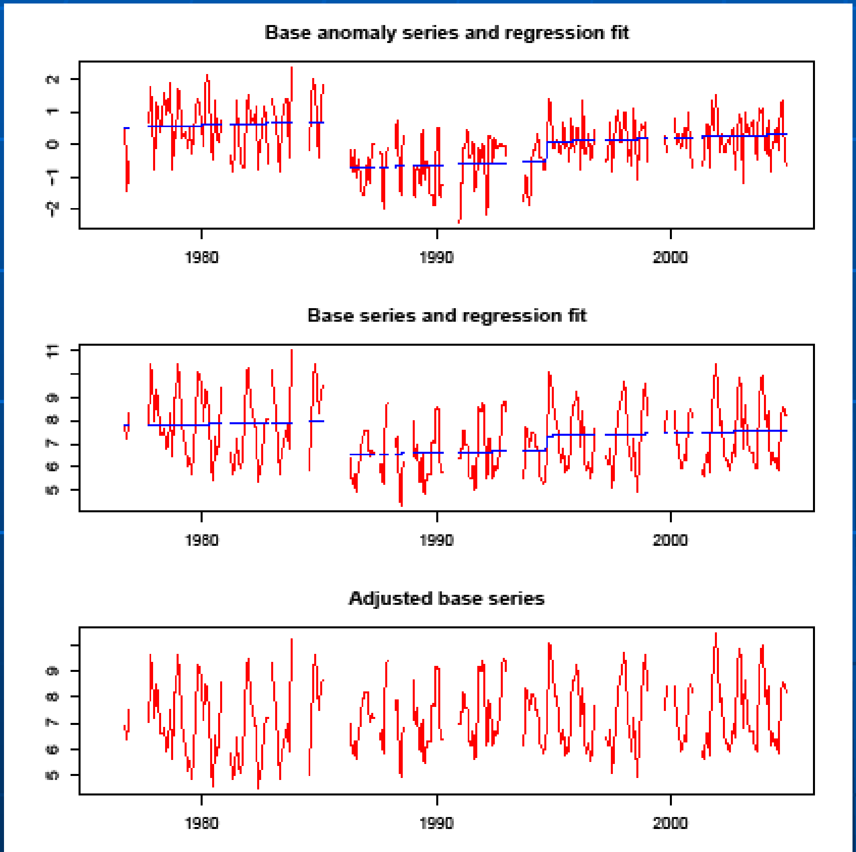
Results of Propellor-vane and Ultrasonic Comparison

- the ultrasonic wind speeds are slightly stronger than propeller-vane wind speeds
- ultrasonic = 0.19 + 1.030 * RMY
- Wave height does not seem to affect the relationship
- Monthly means from sonic about 0.3 m/s > than from RM Young

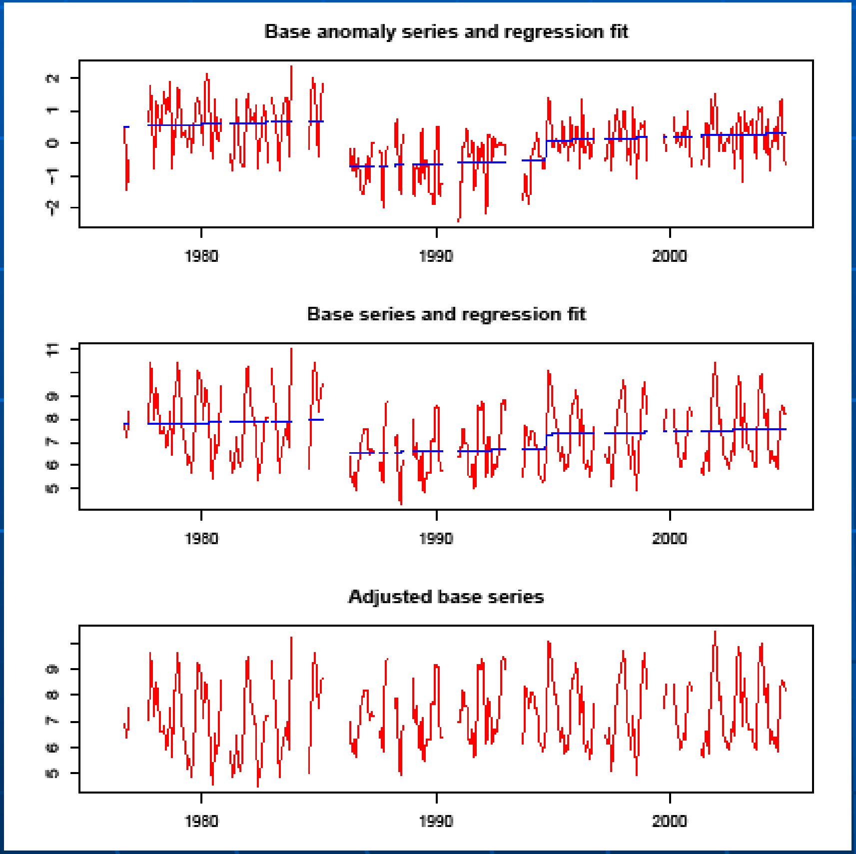
Application to Buoy Time Series

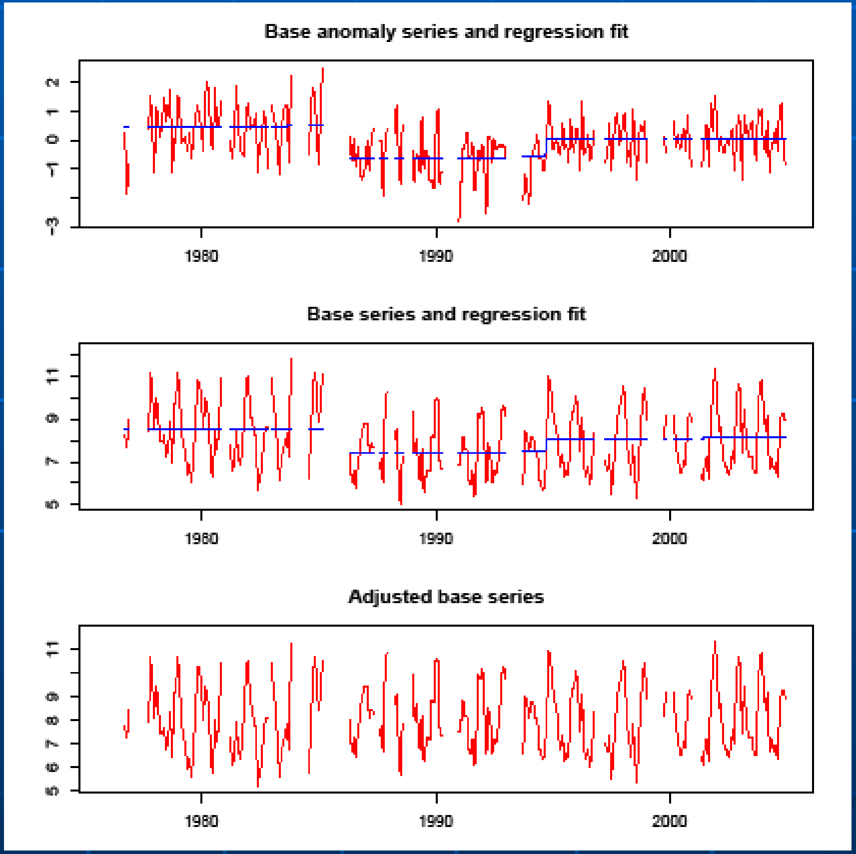
- Buoys 46004 and 46005 have been operating from 1976/10 to the present
- 46004 operated by NDBC to 1988/06, then taken over by EC; 46005 (Washington Buoy) operated by NDBC; we show results for 46005
- To adjust for averaging method, we increased vector winds by 7% for NDBC buoys (1976-1990 for 46005) and by 2% for EC buoys (beginning around 1996)
- To adjust for measurement height (to 10 m) we increased NOMAD winds by 10% (beginning in 1986 for 46005) (the earlier 10D and 12D buoys had anemometers near 10 m)
- To explore the use of the statistical test program RHTest and assess the impacts of the adjustments, we ran RHTest with monthly means calculated from original and then from adjusted winds

Preliminary RHTest results for 46005 Monthly Mean Winds – calculated from original winds



Preliminary RHTest results for 46005 Monthly Mean Winds
– calculated from original winds (left) and from averaging method and ht adjusted winds (right)





Summary and Conclusions

- the scalar-mean wind speed is about 2% higher, overall, than the vector-mean from fully functioning anemometers on Environment Canada 6m NOMAD and 3m Discus buoys
- the median difference increases with increasing wave height to about 4%
- differences are larger with damaged anemometers or faulty compasses (and damage is more likely for 3D buoys in exposed locations)
- differences seem to be larger (~ 7%) for NDBC 3D/DACT scalar vs 6N/GSBP vector means (result similar to Gilhousen 1987)
- ultrasonic wind speeds are about 3% stronger than propeller-vane wind speeds: ultrasonic = 0.19 + 1.030 * RMY
- Application to long-time series show that adjustments for known inhomogeneities do make small differences to monthly means that can affect the trend
- other undocumented changes may still be present in the record