Evaluation of sonic anemometry for the UK Met Office Moored Buoy Network

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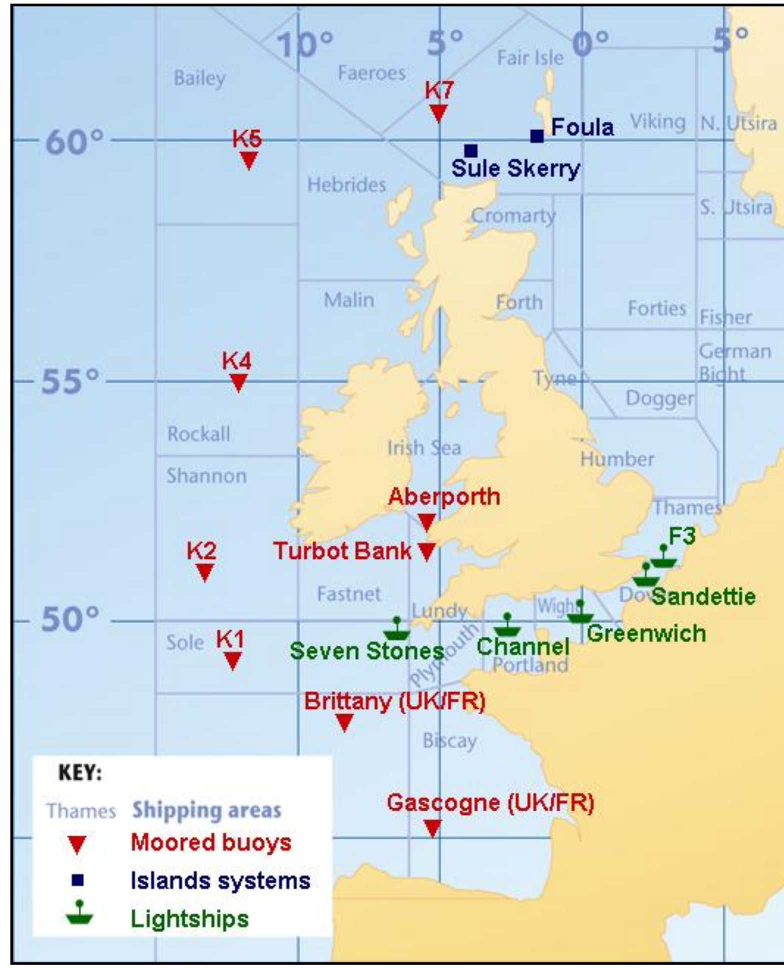
Marine Automatic Weather Station Network

- Marine Automatic Weather Station (MAWS) network presently comprises
  - 9 moored buoys
  - 5 light vessels
  - 2 remote islands

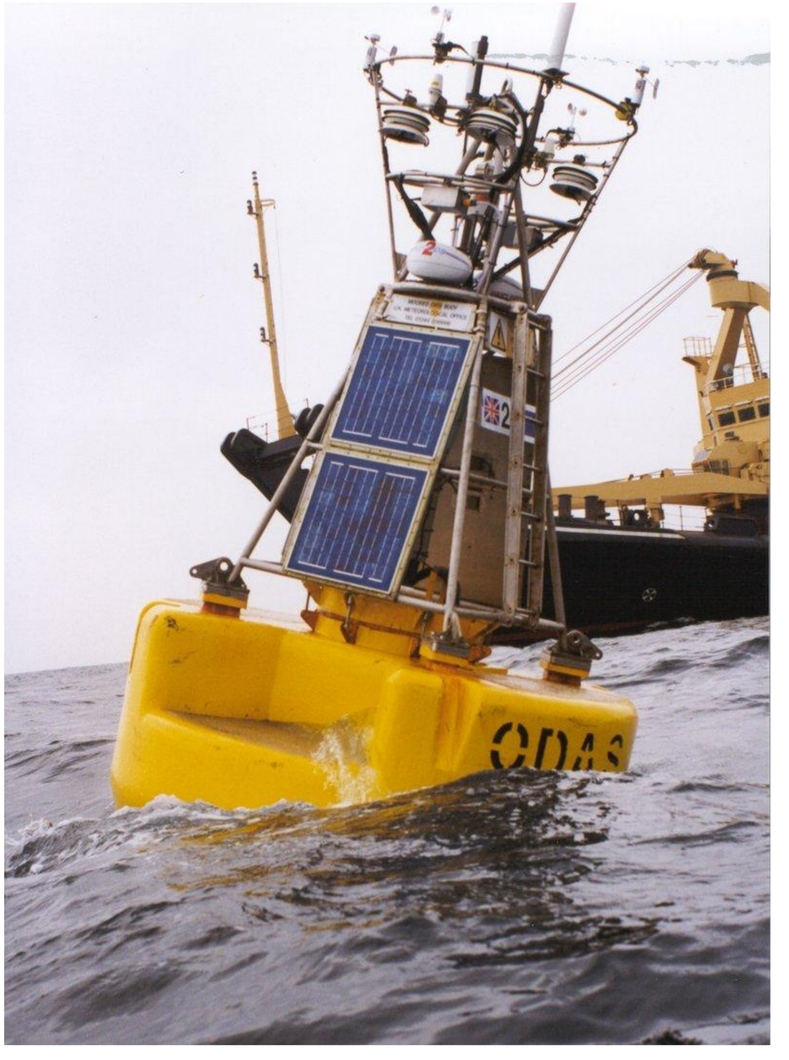


K-series buoys

Met Office

Specifications

- 3 m diameter hull
- 6 m overall height
- 4 m sensor exposure height above sea level
- 1.5 m diameter sensor ring
- Duplicate sensors attached with quick release clamps
- Cross-linked dual control electronics and communications systems for maximum resilience



K-series buoys

- Have been in operation since the early 90s
- Buoys are normally deployed for 2 years with an annual service visit (sensor change and mooring inspection)
- Proven reliability, but ageing control electronics and transmission systems need replacement
- Anemometers are invariably the first sensor to fail, typically after 6 to 9 months at sea

Anemometry system

- Have for many years used a Vector Instruments A100R cup anemometer with a Vector Instruments SRW1G-M wind vane
- To maximise lifetime at sea the anemometers are stripped down and rebuilt before deployment – change oil and additional sealing
- This ‘slows’ the anemometer and a correction of +1.8 kn is applied, also introduces some instrument-to-instrument variability
- At sea, salt water permeates the seals and mechanical failure eventually occurs
- Hence replacement with a sonic anemometer expected to improve operating lifetime

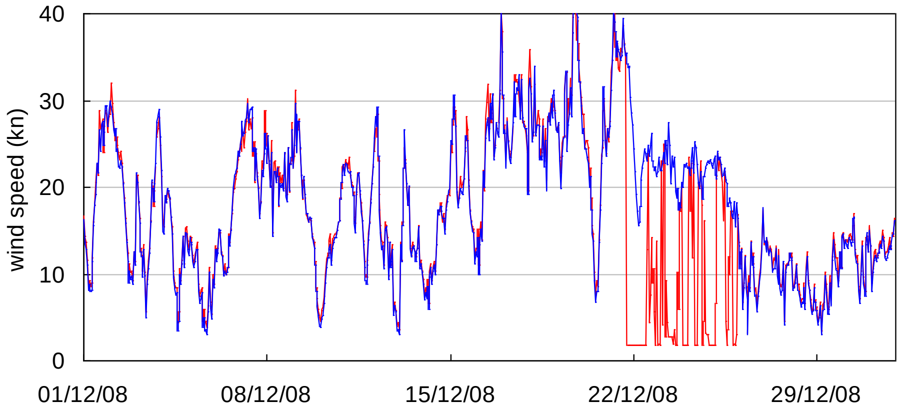
New anemometry system

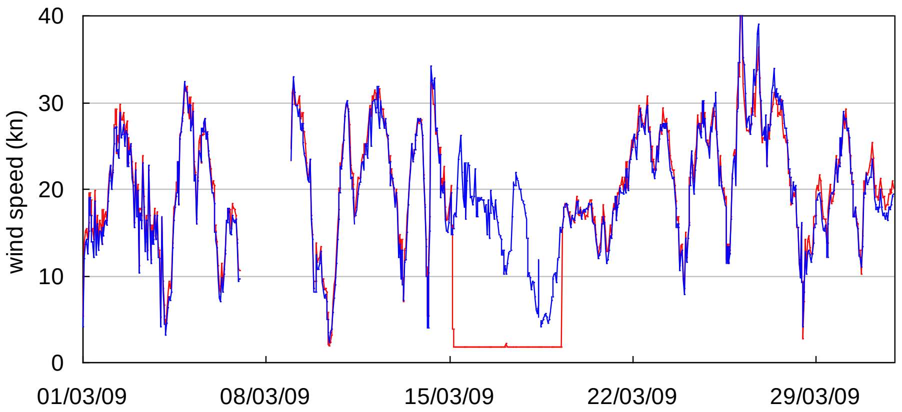
- System based on Gill WindSonic and TrueNorth revolution electronic compass (using an interface board to replicate the analogue output from the Vector instruments sensors)
  - Interim solution until control electronics replaced
- New wind system installed on one side of the buoys to provide a period of comparison alongside a collocated Vector Instruments system
- New wind system deployed on K7 (April 2008), K5 (July 2008) and Brittany and Gascogne (end Sept 2008)
- Data collected over the winter months

Data analysis

- Wind data to end May 2009 analysed
- Raw data as transmitted from buoys reprocessed, to recover winds from both anemometer systems
- No automated QC, but obvious outliers, failures or processing/transmission corruptions removed from statistics

Examples of cup anemometer failure





- Sonic in blue, Vector in red
- Shows periods when cup anemometer on K5 ‘stuck’ during December 2008 and March 2009

K7 deployment

- Only a few months data as communications failed early (became intermittement)
- K7 was replaced in July 2008 with an already-prepared system with dual Vector Instruments anemometers

Period	Speed difference (kn)		Direction difference (deg)	
	Mean (WR-VI)	RMS	Mean (WR-VI)	RMS
24 April to end May 2008	-1.35	1.48	-0.3	7.1
June to 19th July 2008	-1.34	1.44	1.31	6.7

- Sonic (WR) speeds slightly lower than cup and vane system (VI), no significant difference in direction measurements

K5 deployment

Month (2008/2009)	Speed difference (kn)		Direction difference (deg)	
	Mean (WR-VI)	RMS	Mean (WR-VI)	RMS
July	0.03	0.51	1.7	6.3
August	-0.26	0.83	3.4	7.7
September	-0.56	0.99	4.1	7.3
October	0.04	1.00	3.3	7.4
November	-0.05	0.90	1.5	8.5
December	-0.37	0.92	4.3	8.2
January	-0.16	1.12	5.5	9.6
February	-0.28	0.92	3.1	7.0
March	-0.53	1.18	3.3	6.3
April	-0.79	1.08	7.3	9.7
May	-0.65	1.14	6.0	9.4

- Very little bias in wind speed difference (RMS < 1 kn), WR winds are slightly veered
- VI system appears to have survived the period fairly well (other than ‘stuck’ periods)

Brittany deployment

Month (2008/2009)	Speed difference (kn)		Direction difference (deg)	
	Mean (WR-VI)	RMS	Mean (WR-VI)	RMS
October	-0.50	0.73	3.3	6.6
November	0.21	0.71	2.6	6.6
December	0.39	0.71	1.8	5.8

- Comms system failure late December after which observation became intermittent (ex K7 hull)
- WR system gave slightly higher wind speeds from November at lower wind speeds (possibly indicating increased friction in VI system)
- WR directions slightly veered

Gascogne deployment

Month (2008/2009)	Speed difference (kn)		Direction difference (deg)	
	Mean (WR-VI)	RMS	Mean (WR-VI)	RMS
October	-0.36	0.54	-5.7	7.4
November	-0.30	0.94	-5.9	6.7
December	-0.05	0.54	-6.3	7.1
January	0.15	0.61	-5.9	6.6
February	-0.03	0.49	-7.5	8.0
March	-0.34	0.47	-6.8	7.5
April	-0.55	0.66	-5.8	6.7
May	-0.74	0.88	-6.0	8.6

- Wind speeds agree well throughout the deployment, WR speeds slightly lower
- WR directions slightly backed relative to VI
- Buoy serviced in early June and anemometers replaced

K7 dual VI redeployment

Month (2008/2009)	Speed difference (kn)		Direction difference (deg)	
	Mean	RMS	Mean (WR-VI)	RMS
August	0.17	0.49	-0.7	5.6
September	0.19	0.55	-0.3	6.1
October	-0.08	0.92	-1.7	5.1
November	0.20	0.99	-1.2	5.0
December	-0.68	2.19	-1.1	6.5
January	1.12	1.46	0.0	5.0
February	2.34	2.42	-1.1	4.3
March	2.19	2.38	-0.7	5.2
April	2.33	2.55	-0.1	4.7
May	-0.48	1.82	-1.0	6.0

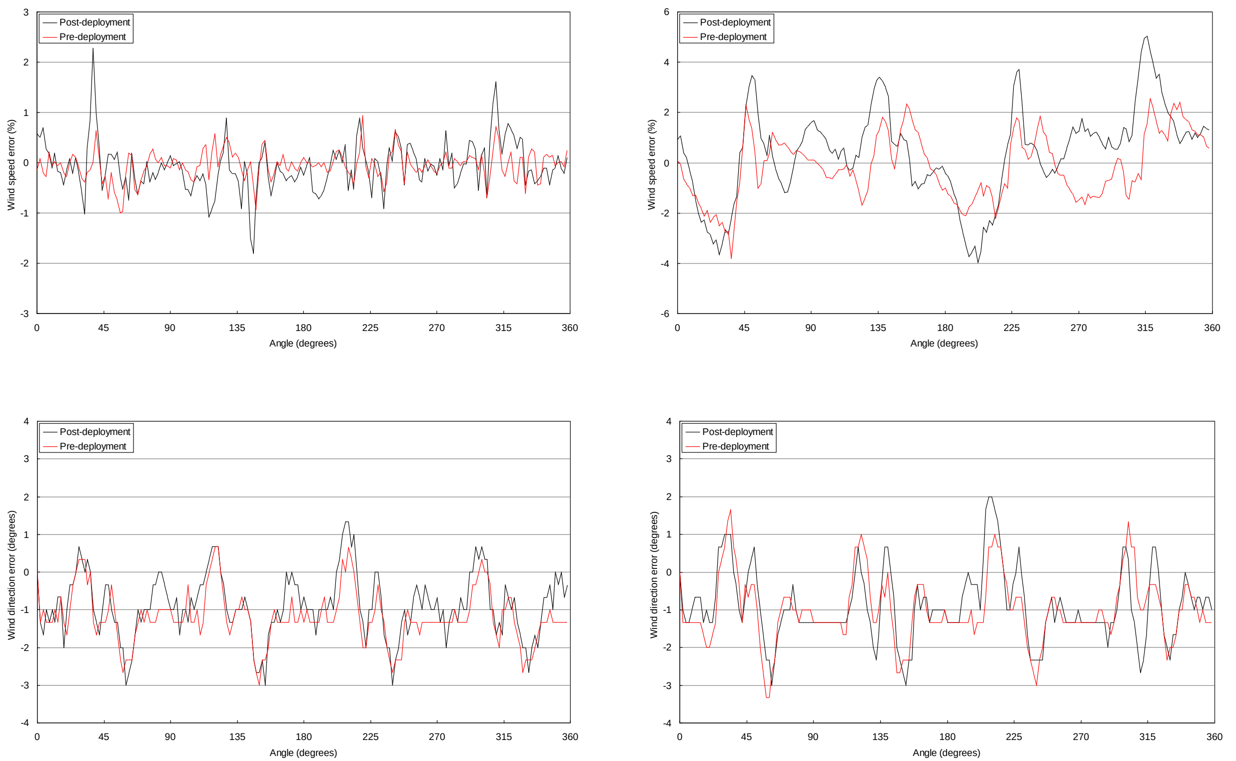
- Speeds agree well in August and September (lower winds)
- January - April anemo 1 (primary) consistently higher than anemo 2
- ECMWF/Met Office monitoring against NWP shows bias increased from -1.0 kn (April) to -2.7 kn in May, suggesting that anemo 1 was increasingly under-reading
- Results consistent with anemo 2 starting to slow from January 2009 and anemo 1 starting to slow from the end of April, in May both anemometers were under-reading
- Wind directions agree well

Summary

- See periods when the VI anemometers ‘stick’
- Results from K7 show degradations in wind speeds in both VI cup anemometers, can be difficult to identify when degradation is gradual
- Cannot regard wind speeds from VI cup anemometer as being of climate quality over extended deployments
- Both VI cup anemometers on K7 have subsequently failed, while (as at Sept 09) WR system on K5 still working well

Gascogne WindSonic post-deployment calibration

- Wind speed (top) and direction (bottom) errors at 12 m/s (left) and 32 m/s (right); red is pre-deployment, black is post-deployment

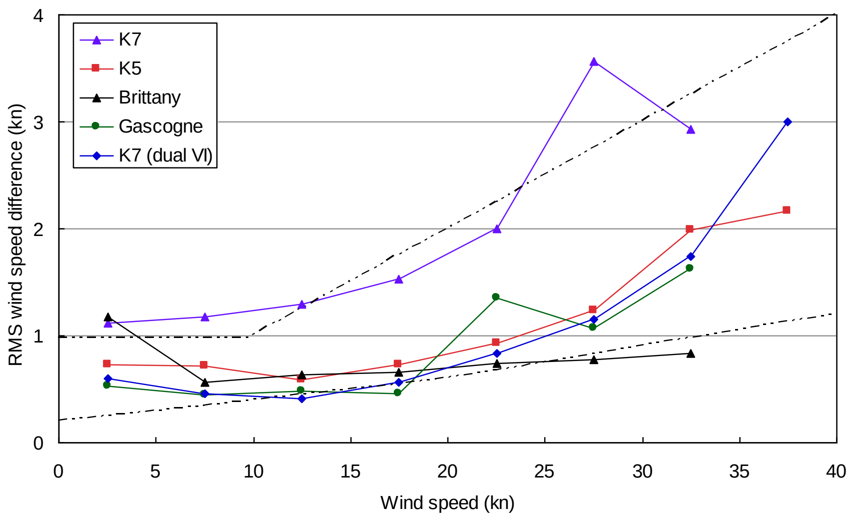


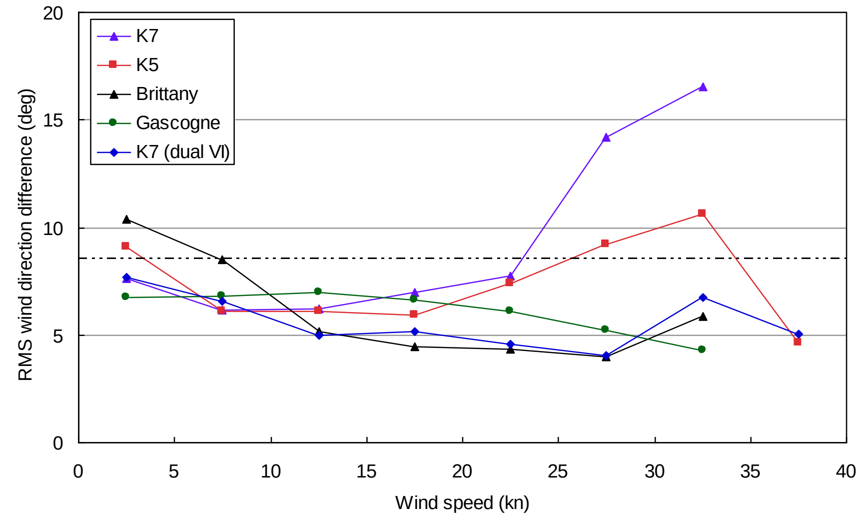
Gascogne post-deployment WindSonic calibration

Calibration	Tunnel wind speed (m/s)	Wind speed		Wind direction difference	
		Mean	St dev	Mean	St dev
Pre-deployment	12	11.99	0.04	-1.18	0.71
	32	31.95	0.42	-1.00	0.88
Post-deployment	12	11.99	0.06	-0.88	0.84
	32	32.12	0.59	-0.90	0.94

- For wind speed, overall difference in accuracy pre- and post-deployment is small
- For direction, overall difference is negligible
- Shows no evidence of instrument accuracy having deteriorated after 8 months at sea

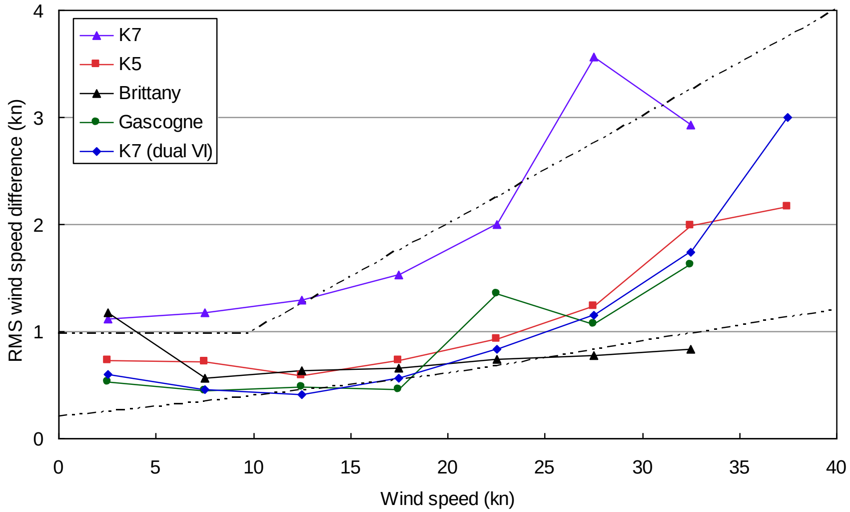
Instrument differences with increasing wind speeds

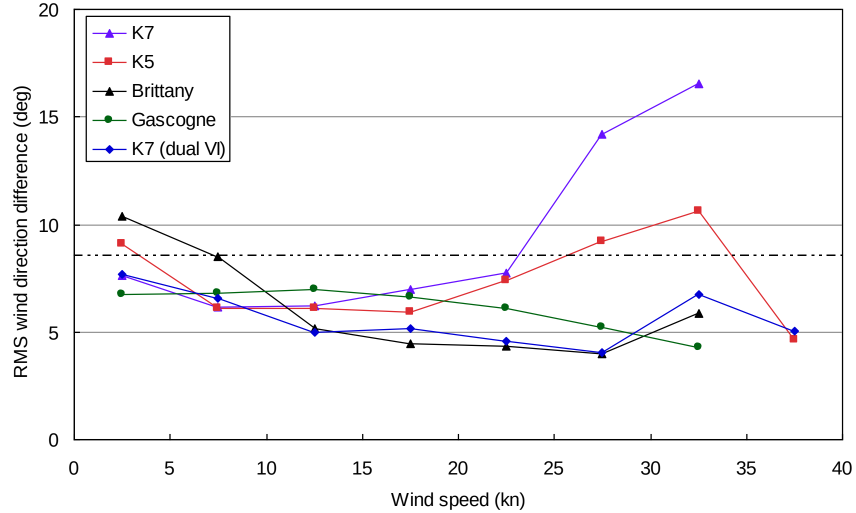




- RMS differenced based on first 3 months of deployment
- Lower dashed line is difference based on manufacturers quoted accuracies
- Upper dashed line (for speed) is 1x the WMO guideline accuracy

Instrument differences with increasing wind speeds





- Agreement poorest for K7, buoy had been on quayside for many months prior to deployment, but still within 2x WMO guideline accuracy
- For all other systems (apart from Brittany at <5 kn) speeds agree to within 1x WMO guideline accuracy
- Differences between K7 with dual VI anemometers is not significantly different to those for buoys with WR systems
- RMS difference in speeds tends to increase with wind speed and is greater than would be expected if both systems met their quoted accuracies

Conclusions

- Differences in speed between WR and VI systems generally small although greater than would be given by manufacturers specifications
- Wind speed differences/errors increase with wind speed, no obvious signal for wind direction
- WR/VI differences are not significantly different to those measured using dual VI cup and vane systems
- Results show wind speed measurements from VI cup anemometer do degrade with time, no evidence of any deterioration in the WindSonic

Conclusions

- Although initial accuracy of WR system may be less than the VI system, it is expected that it will retain its accuracy for longer and so provide more consistent wind measurements
- Hence it is planned that from 2010 dual WR systems are deployed across the entire network
- Recommended that wind tunnel calibration of the WindSonics is carried out before deployment and after recovery (nominally 2 years)