

ASSESSING THE IMPACT OF DIFFERENT MEASUREMENT TIME INTERVALS  
ON OBSERVED LONG-TERM WIND SPEED TRENDSCESAR AZORIN-MOLINA<sup>1</sup>, SERGIO M. VICENTE-SERRANO<sup>1</sup>, TIM McVICAR<sup>2</sup>, SONIA JEREZ<sup>3</sup>, JESUS REVUELTO<sup>1</sup>, and J.I. LOPEZ-MORENO<sup>1</sup>

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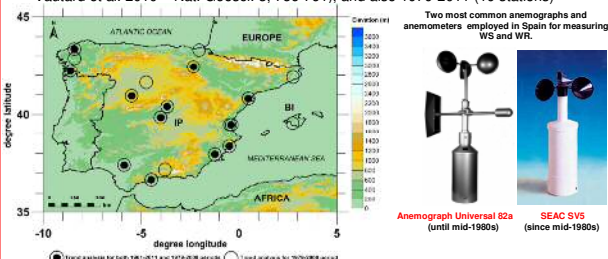
**ABSTRACT.** During the last two decades climate studies have reported a tendency toward a decline in measured near-surface wind speed in some regions of Europe, North America, Asia and Australia. This weakening in observed wind speed has been recently termed "global stilling", showing a worldwide average trend of  $-0.140 \text{ m s}^{-1} \text{ dec}^{-1}$  during last 50-years. The precise cause of the "global stilling" remains largely uncertain and has been hypothetically attributed to several factors, mainly related to: (i) an increasing surface roughness (i.e. forest growth, land use changes, and urbanization); (ii) a slowdown in large-scale atmospheric circulation; (iii) instrumental drifts and technological improvements, maintenance, and shifts in measurements sites and calibration issues; (iv) sunlight dimming due to air pollution; and (v) astronomical changes. This study proposed a novel investigation aimed at analyzing how different measurement time intervals used to calculate a wind speed series can affect the sign and magnitude of long-term wind speed trends. For instance, National Weather Services across the globe estimate daily average wind speed using different time intervals and formulae that may affect the trend results. Here we analyzed near-surface wind speed trends recorded at 19 land-based stations across Spain comparing monthly mean wind speed series obtained from: (a) daily mean wind speed data averaged from standard 10-min mean observations at 0000, 0700, 1300 and 1800 UTC; and (b) average wind speed of 24 hourly measurements (i.e., wind run measurements) from 0000 to 2400 UTC. As a complementary analysis, in this study we also quantified the impact of anemometer drift (i.e. bearing malfunction) by presenting preliminary results (i.e. 11 months of paired measurements) from a comparison of one new anemometer sensor against one malfunctioned anemometer sensor due to old bearings.

## Wind Speed Series - Measurement Time Intervals

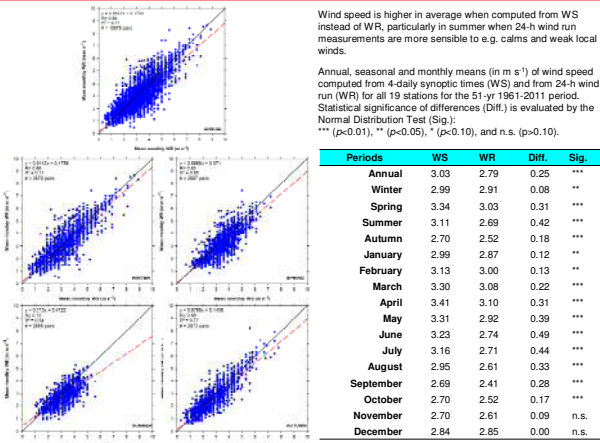
- Data:** We compared monthly wind speed series obtained from:
  - (a) Daily mean wind speed data averaged from standard 10-min mean observations at 0000, 0700, 1300 and 1800 UTC (hereafter **WS**); vs.
  - (b) Daily mean wind speed data averaged from wind speed of 24 hourly measurements (i.e., wind run) from 0000 to 2400 UTC (hereafter **WR**).

- Stations:** 19 land-based stations across Spain.

- Study periods:** 1961-2011 (12 stations), 1979-2008 (19 stations; to be compared with Vautard et al. 2010 - Nat. Geosci. 3, 756-761), and also 1979-2011 (19 stations)

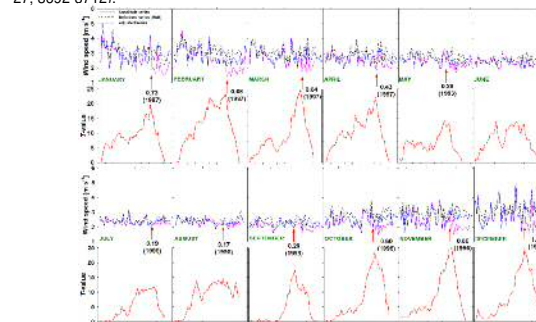


## Annual, Seasonal and Monthly Wind Speed Differences



## Quality Control, Reconstruction and Homogenization

Because of the limited metadata, the following multistep approach was applied to create robust wind speed series of WS and WR for comparison: (i) **quality control**, (ii) **reconstruction**, and (iii) **homogenization**. For details see Azorin-Molina et al. 2014 (JCLI, 27, 3692-3712).



An example of monthly original (candidate) **MMS** reference and adjusted series and corresponding T-values of the SNHT test at monthly basis for 1961-2011. The amounts of change and years of breakpoint (in brackets) are highlighted with an arrow; for June no significant breakpoint ( $p < 0.05$ ) was detected.

## % of Stations with + and - wind speed trends

Relative frequency of stations showing significant (at  $p < 0.05$  and  $p < 0.10$ ) and non-significant (at  $p < 0.10$ ) negative and positive wind speed trends annually and seasonally for WR and WS for 1979-2008 (19 stations). For the three p-level thresholds, relative frequencies are calculated with respect to the total number of stations showing negative or positive tendencies.

Periods	WR						WS					
	Negative	Negative	Negative	Negative	Positive	Positive	Negative	Negative	Negative	Negative	Positive	Positive
	$p < 0.05$	$p < 0.10$	$p < 0.10$	$p < 0.10$	$p < 0.05$	$p < 0.10$	$p < 0.05$	$p < 0.10$	$p < 0.10$	$p < 0.05$	$p < 0.10$	$p < 0.10$
Annual	36.8	57.1	57.1	42.9	63.2	16.7	63.2	50.0	58.3	41.7	36.8	14.3
Winter (DJF)	89.5	35.3	35.3	64.7	10.5	0.0	50.0	50.0	50.0	50.0	50.0	50.0
Spring (MAM)	47.4	44.4	44.4	55.6	52.6	10.0	10.0	90.0	90.0	90.0	90.0	90.0
Summer (JJA)	36.8	28.6	28.6	71.4	63.2	33.3	66.7	33.3	33.3	33.3	66.7	33.3
Autumn (SON)	21.1	0.0	0.0	100.0	78.9	26.7	40.0	60.0	60.0	60.0	40.0	60.0

Periods	WR						WS					
	Negative	Negative	Negative	Negative	Positive	Positive	Negative	Negative	Negative	Negative	Positive	Positive
	$p < 0.05$	$p < 0.10$	$p < 0.10$	$p < 0.10$	$p < 0.05$	$p < 0.10$	$p < 0.05$	$p < 0.10$	$p < 0.10$	$p < 0.05$	$p < 0.10$	$p < 0.10$
Annual	63.2	50.0	58.3	41.7	36.8	14.3	14.3	85.7	85.7	85.7	14.3	85.7
Winter (DJF)	94.7	38.9	44.4	55.6	5.3	0.0	0.0	100.0	100.0	100.0	0.0	100.0
Spring (MAM)	84.2	31.3	37.5	62.5	15.8	33.3	66.7	33.3	33.3	33.3	66.7	33.3
Summer (JJA)	52.6	30.0	50.0	50.0	47.4	77.8	33.3	66.7	66.7	66.7	33.3	66.7
Autumn (SON)	47.4	11.1	11.1	88.9	52.6	50.0	50.0	50.0	50.0	50.0	50.0	50.0

## Impact of anemometer drift

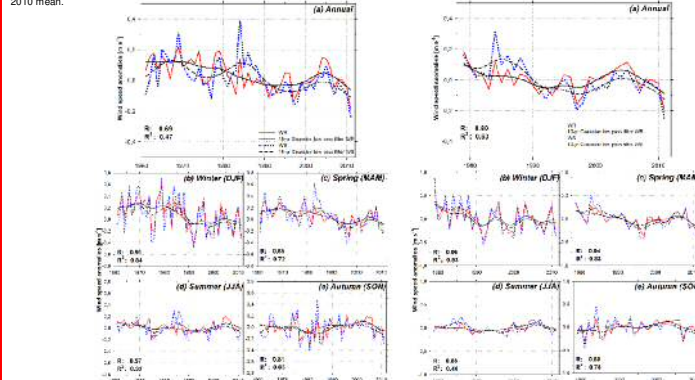
Periods	New	Old	Diff.	Sig.
Annual	2.18	1.84	0.34	***
January	2.60	2.17	0.44	***
February	3.12	2.63	0.50	***
March	2.92	2.54	0.38	***
April	2.77	2.35	0.42	***
May	2.16	1.75	0.41	***
June	2.01	1.67	0.34	***
July	2.10	1.77	0.33	***
August	1.81	1.53	0.29	***
September	1.51	1.21	0.31	***
October	1.24	1.05	0.19	***
November	1.76	1.55	0.20	***
December	n.d.	n.d.	n.d.	n.d.

Intercomparison of one new SEAC SV5 anemometer sensor against one malfunctioned SEAC SV5 due to old bearings. Differences (in  $\text{m s}^{-1}$ ) are evaluated by the Normal Distribution Test (Sig.; see above).



## Annual, Seasonal and Monthly Trends 1961-2011 &amp; 1979-2008

Mean annual and seasonal wind speed anomalies ( $\text{m s}^{-1}$ ) series for WR (red solid line) and WS (blue dotted line) from 1961-2011 (left) and 1979-2011 (right). The 15- and 10-year Gaussian low-pass filter is also shown with a black solid line for WR and with a black dashed line for WS. The series are expressed as anomalies from the 1981-2010 mean.

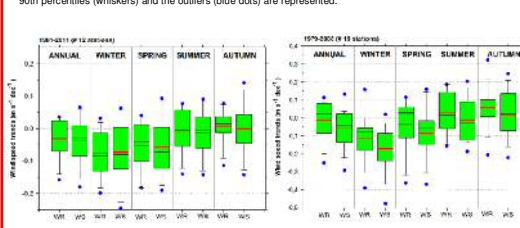


Annual and seasonal wind speed trends averaged for WR and WS for 1961-2011 (12 stations), and 1979-2011 and 1979-2008 (19 stations). Values are expressed as  $\text{m s}^{-1} \text{ dec}^{-1}$ . Statistically significant trends were defined as those  $p < 0.10$  (in bold) and  $p < 0.05$  (in bold and in parenthesis).

Periods	WR			WS		
	1961-2011	1979-2011	1979-2008	1961-2011	1979-2011	1979-2008
Annual	(-0.033)	-0.022	-0.011	(-0.036)	(-0.063)	(-0.057)
Winter (DJF)	(-0.078)	-0.085	-0.110	(-0.072)	(-0.140)	(-0.171)
Spring (MAM)	(-0.054)	(-0.063)	-0.038	(-0.057)	(-0.098)	(-0.085)
Summer (JJA)	-0.007	0.019	0.031	-0.013	-0.020	-0.013
Autumn (SON)	0.008	0.031	0.058	0.000	-0.008	0.018

## Statistical summary of wind speed trends

Box-and-whisker plots of wind speed trends for comparison between (i) WR, and (ii) WS for annual and seasonal periods. The mean (red line), the median (black line), the 25th and 75th percentile range (boxes), the 10th and 90th percentiles (whiskers) and the outliers (blue dots) are represented.



## Conclusions

The main findings of this assessment of the impact of two different measurement time intervals on observed long-term wind speed trends are the following:

- We detected that monthly mean wind speed data values are greater when averaged from standard 10-min mean observations at 0000, 0700, 1300 and 1800 UTC (WS) than from 24-hourly wind run measurements (WR), particularly in summer.
- We found that the different measurement time intervals used has an impact on the sign and magnitude of wind speed trends, showing WR data less negative long-term wind speed trends than WS.
- Additionally, we presented preliminary results of an ongoing intercomparison of anemometers aimed at evaluating the impact of anemometer drift on wind speed measurements. Statistically significant differences are found.