Towards a new tall tower database

Building a quality controlled and homogenized database of wind observations from existing tall towers

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1. Motivation

- In a worldwide context of GHG emission reductions, wind power is a key player to ensure mitigation of climate change.
- A lot of research is undergoing at several levels to better understand and characterize wind speed climate and reduce risks of this variable electricity generation source. But the lack of quality observations can jeopardize this goal.
- Meteorological observations at turbine heights are essential to derive production estimates. Instrumented tall towers provide measurements at several heights and lead to a better characterization of boundary layer processes (Figure 1).
- But those observations are scarce and harsh to find. Although several institutions have instrumented towers, there is a lack of coordination regarding data access, formatting and metadata. The information is sparse, hard to find and very difficult to use due to the diversity of formats and qualities.
- INDECIS project (ERA4CS) aims to inventory and catalog these existing datasets and develop new tools to ensure their quality.

1.1 Objectives

1. Identify and **collect** sparse wind observations from existing tall towers. Build a database with a single access point and a common data format.
2. Develop and apply a set of **quality control** rules to ensure the reliability of data.
3. Exploit the availability of sensor redundancy to **fill in** data gaps and detect inhomogeneities.

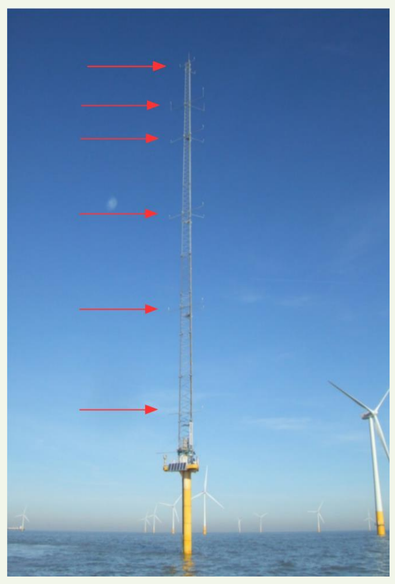

Figure 1. Kentish Flats offshore tall tower, near UK shores. Red arrows indicate the levels of measurement, ranging from 13 to 80 meters above platform level. *Source: www.marinedataexchange.co.uk*

2. Site identification

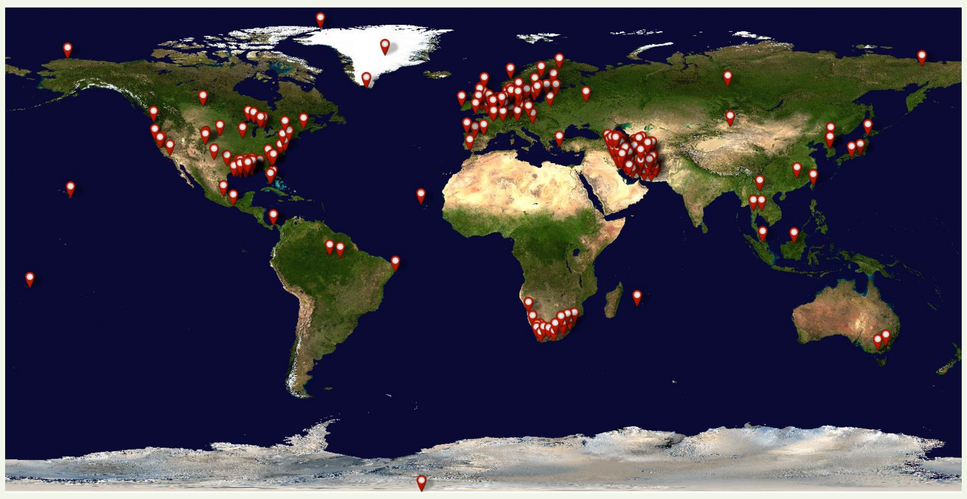

Figure 2. Global distribution of the 311 identified masts.

- **311 instrumented towers** from several institutions have been **identified** (Figure 2). Data from 214 sites have been processed so far.
- Most of the sites are located in Europe and North America, with some clusters from national databases.
- The database includes offshore sites, flat and complex topography and forested areas.
- Tower heights range from 20 to 400 meters.

3. Data outlook

- Wind speed and wind direction at multiple heights have been collected for each site. Temperature, pressure and relative humidity is also available for most of sites and have been included for completeness.
- Record lengths range from 1 to 37 years (Figure 3), while **time sampling interval** varies from 1-minutely to 1-hourly averages.
- Different **data policies** are imposed by the original data owners: freely available, available with conditions, prohibited transferring to thirds or even not downloadable.
- This raw database (INDECIS Raw dataset) aims to be accessible by the **first half of 2019**, always respecting the restrictions imposed by the data providers.

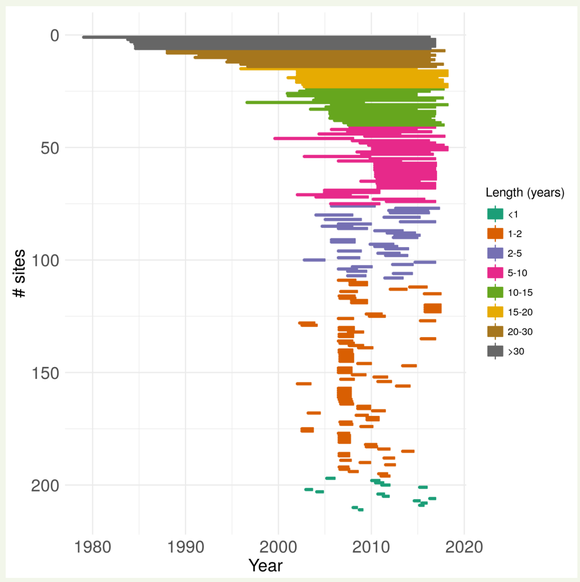

Figure 3. Periods of record of the 214 processed tall towers.

4. Sensor redundancy

- It is common practice to instrument tall towers with 2 or 3 **booms** at the same height, with different orientations.
- This allows the placement of more than one sensor per level (**redundancy**).
- A sensor **failure** can be corrected with other sensors at the same height.
- Figure 4 shows an example of a sensor failure (top). This time series can be reconstructed using, if possible, simultaneous measurements taken by a sensor at a same height (center). Then, a time series without inhomogeneities can be obtained (bottom).

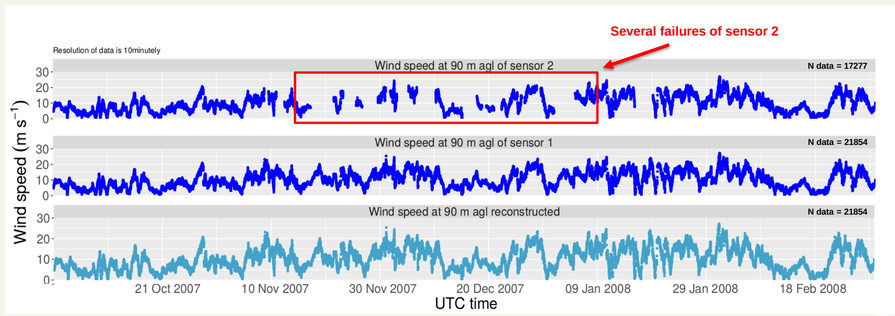

Figure 4. Reconstruction of a time series using sensor redundancy for Docking Shoal met mast, UK. Central and top plots show the original time series. Red box indicates when sensor 2 experienced failures. Resulting reconstructed time series is displayed at bottom.

5. Quality Control suite

- A set of **17 QC checks** have been considered to detect errors and problems in the data (Figure 5).
- Adapted from the **Guide to the Global Observing System of the WMO** published in 2007.
- After running the QC software suite, each observation is **flagged** according to their level of reliability. This allows users impose their own degree of restraint.

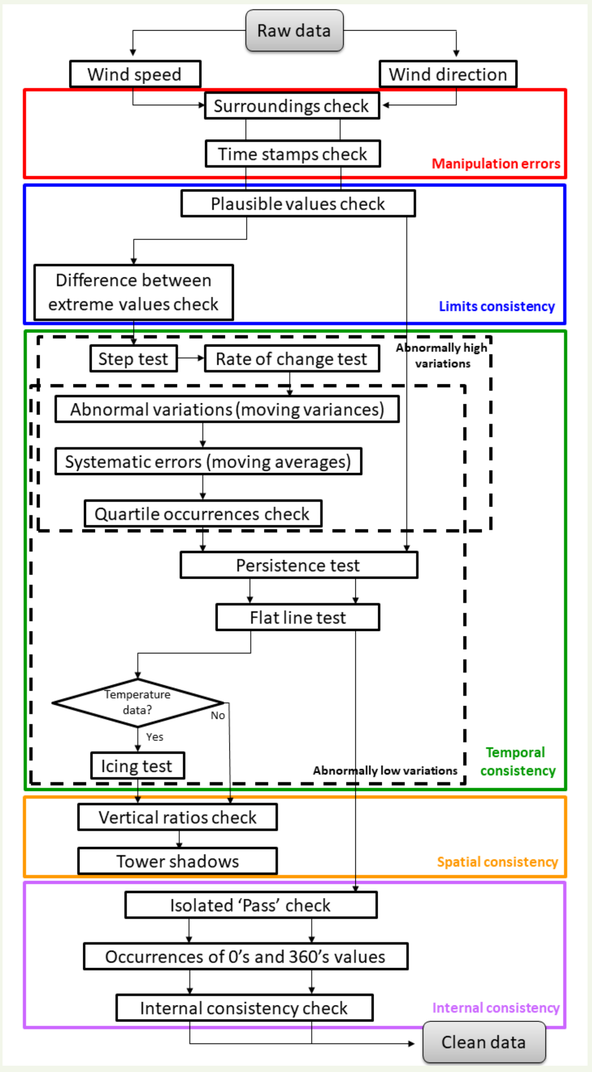

Figure 5. Flux diagram of the quality control routines. The five colored rectangles comprise the checks associated with manipulation errors, limits consistency, temporal and spatial consistency and internal consistency.

6. Unique features of the dataset

- The **particularities** of tall tower observations (i.e. measurements at **several heights** or sensor **redundancy**) allow the inclusion of other **non-standard QC checks** to ensure spatial coherency.
- As an example, a couple of QC checks are shown below. Figure 6 presents the detection of an icing event, whilst Figure 7 shows the effects of the tower pole over the anemometers by a reduction of the measured wind speeds.

Example 1: detection of an icing event

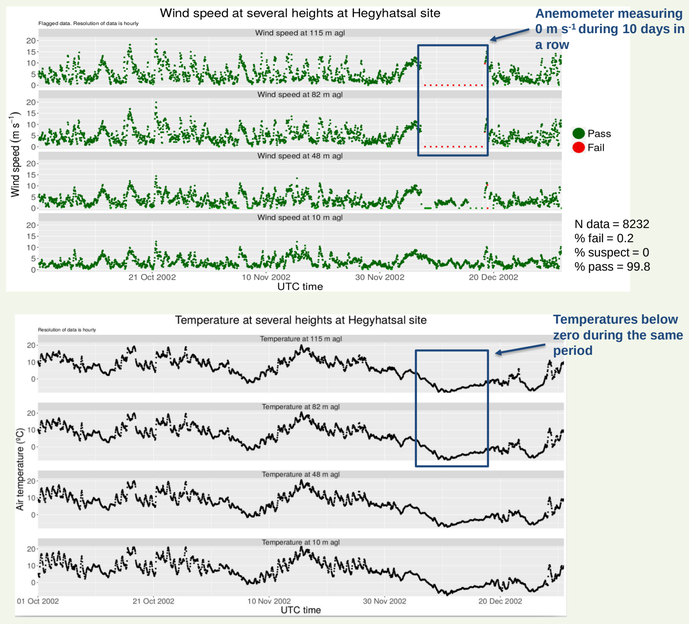

Figure 6. Detection of an icing event during December 2002 in Hegyhátsál tower, HU. Top image displays the wind speeds at different levels of measurement. Each measurement is flagged depending on whether the test passes (green) or not (red). Bottom image represents temperature for these heights. Blue square in both images highlights the icing event.

Example 2: tower structure shadowing anemometers

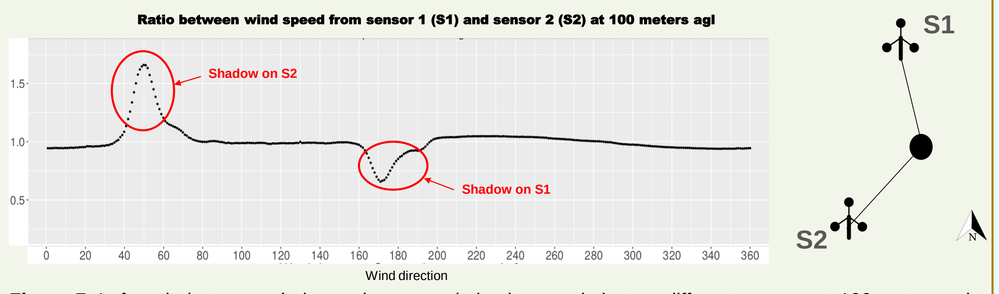

Figure 7. Left: ratio between wind speed measured simultaneously by two different sensors at 100 meters agl at FINO3 met mast, DE. The quotients have been grouped according to wind direction in groups of 1º. Right: anemometers layout at 100 m level of FINO3 mast[1].

- The **tower structure** can reduce wind speed downwind, producing erroneous measurements that must be detected.
- Figure 7 shows an example of a tower shadow by representing the **ratio of wind speeds** measured simultaneously by two different anemometers: S1 and S2. Then, these wind speeds are grouped by wind directions.
- A maximum is observed for the 50º of direction. NE winds (around 45º of direction) are **reduced downwind** when measured by S2. Hence, wind speeds measured by S1 do not agree with the obtained from S2 for the same period of time.
- An analogous situation is observed for S1 for SSE winds.

[1] We acknowledge the FINO project, the Bundesministerium fuer Wirtschaft und Energie (BMWi), and the Projekttraeger Juelich (PTJ) for sharing their data.

7. Conclusions

- A database gathering meteorological observations from instrumented tall towers has been created. Efforts have been made to assure high quality wind observations.
- A total of 214 sites constitute the database. It is expected to increase this number by adding new observations.
- Data aims to be publicly available during the first half of 2019, always depending on the restrictions imposed by data providers.
- Sensor redundancy allows the completion of time series if one of them experiences a failure.
- 17 quality control routines have been considered to detect problems in the data.
- The special nature of the dataset allows the inclusion of non-standard checks.

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