50 Year Wind Speeds from the USAF Data Set

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Abstract:

Maximum wind speeds are an important consideration in some regions for the placement of wind turbines for electricity production. The current IEC61400 (International Electrotechnical Commission) wind turbine classification scheme uses three standardized categories (Classes I, II, and III) that are based on different wind strengths, including average wind speed for normal operating conditions and the 50-year extreme gust over 3 seconds to define turbine survival thresholds. For Class I turbines (the most robust category) the 50-year extreme gust threshold is 70 m/s, and this represents the maximum wind speed survival threshold. A recent study based on a numerical model has indicated that wind conditions during the most severe hurricanes exceed wind turbine survivability limits. This supports other published case studies that document wind turbine damage during severe cyclones and typhoons in south and east Asia. For economic viability, wind farms must be placed in areas where hurricanes are not too frequent in order to minimize the risk of damage during an operational lifetime that spans about 20 years. The present contribution uses the USAF meteorological data set to derive statistics of maximum wind speeds that can be expected with return intervals of 50 years. The contribution shows distribution maps of 50 year wind speeds, highlighting areas where damaging winds may be expected during the operational lifetime of a wind turbine.
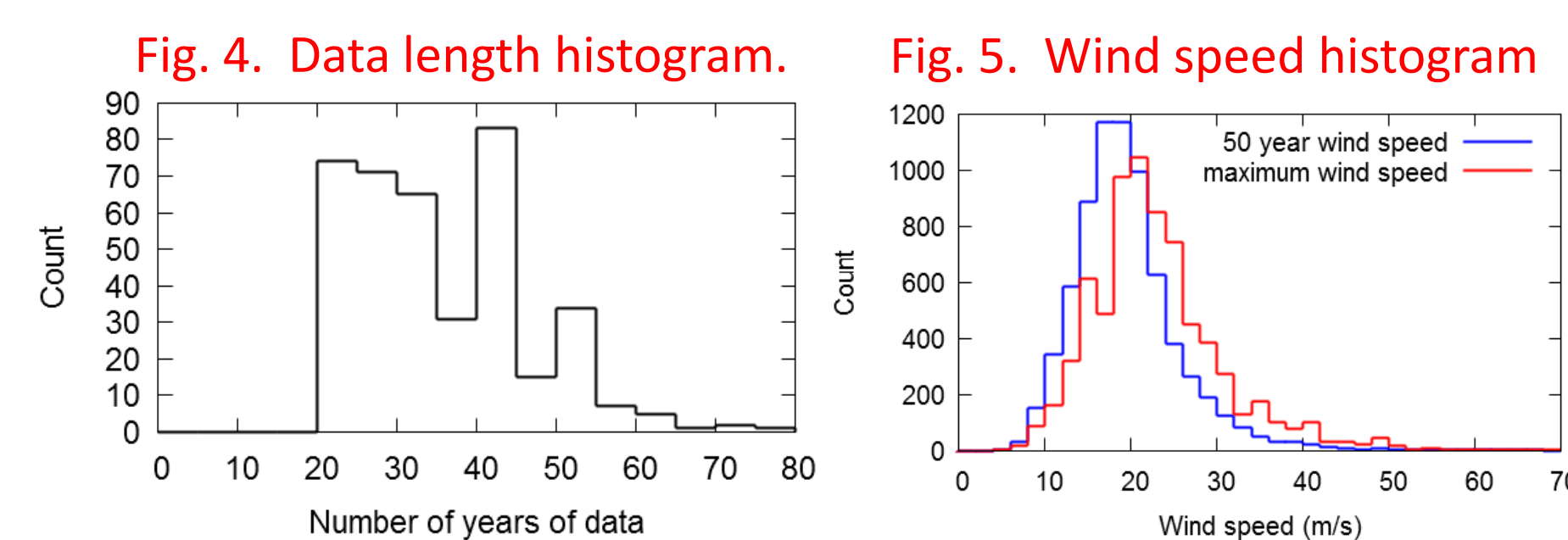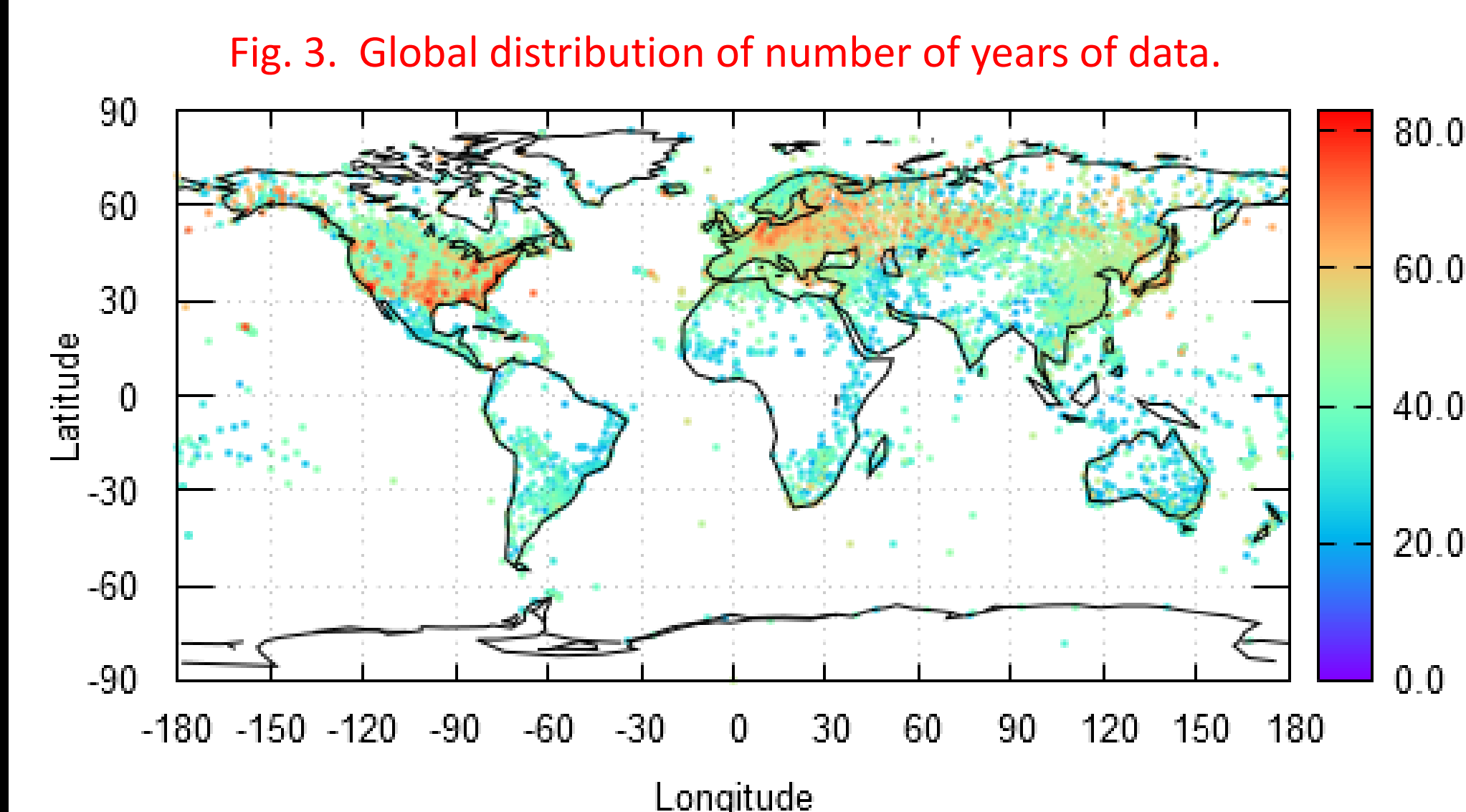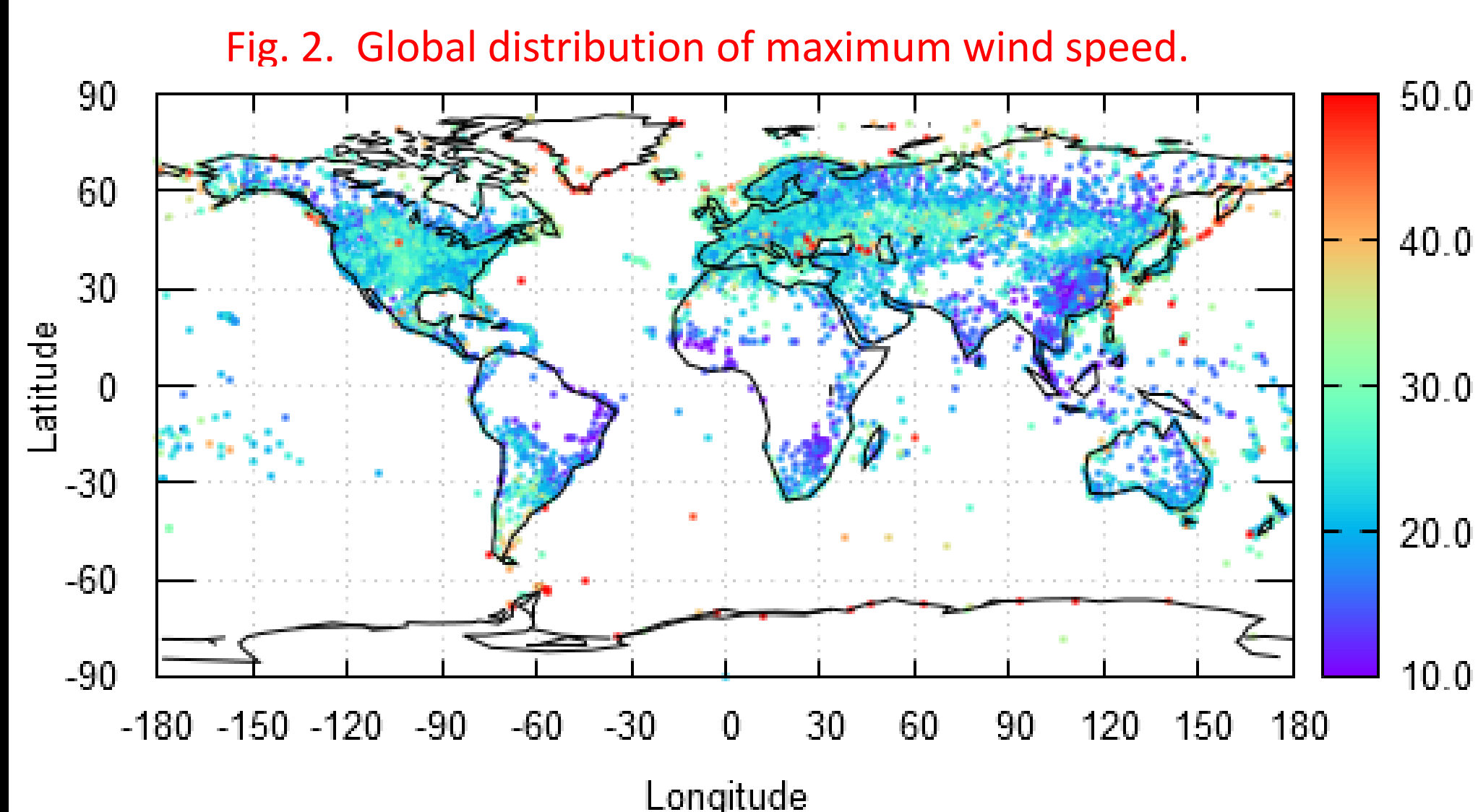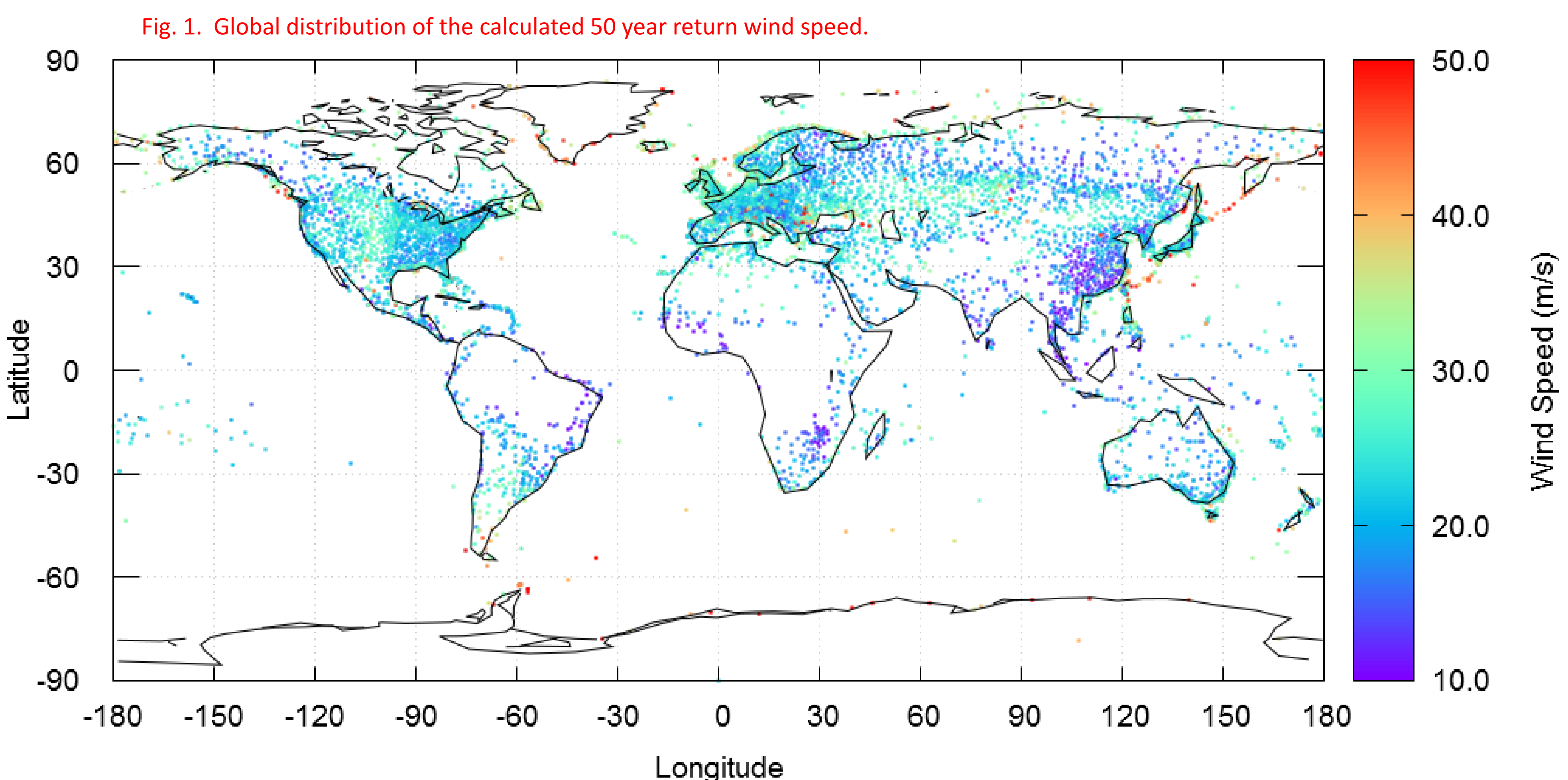
Methods:

The USAF dataset is a compilation of the raw meteorological measurements for stations from around the globe starting from ~1901. The density of measurements increases with time, with data from more and more stations becoming available through the 20th century. The USAF measurements were compiled from different source networks that were set up for different meteorological, climate, and aviation objectives. For this project, data was selected from the WMO (World Meteorological Organization), ICAO (International Civil Aviation Organization), AFWA (Air Force Weather Agency), and CMAN (Coastal-Marine Automated Network) networks, yielding ~12000 stations in the first count.

The procedure to assess the 50-year wind speed uses the annual maximum method with the Gumbel distribution. For each station, the number of complete years of data was assessed, and only stations with >20 years of data were used in the analysis. This sifting procedure resulted in a reduced dataset of ~7100 stations. For each station, the maximum wind speed for each year was determined. These were ranked in descending order and a Gumbel linear fit made according to the procedure of Palutikof et al (1999). The fitted line was extrapolated to yield the wind speed at the 50-year return interval.

In addition to the 50 year wind speeds, information is presented on the length of the data sets in the analysis and the maximum observed wind speeds.

Spatial Distribution of the 50-year Wind Speed

Fig. 1. Global distribution of the calculated 50 year return wind speed.

Fig. 2. Global distribution of maximum wind speed.

Fig. 3. Global distribution of number of years of data.

Fig. 4. Data length histogram.

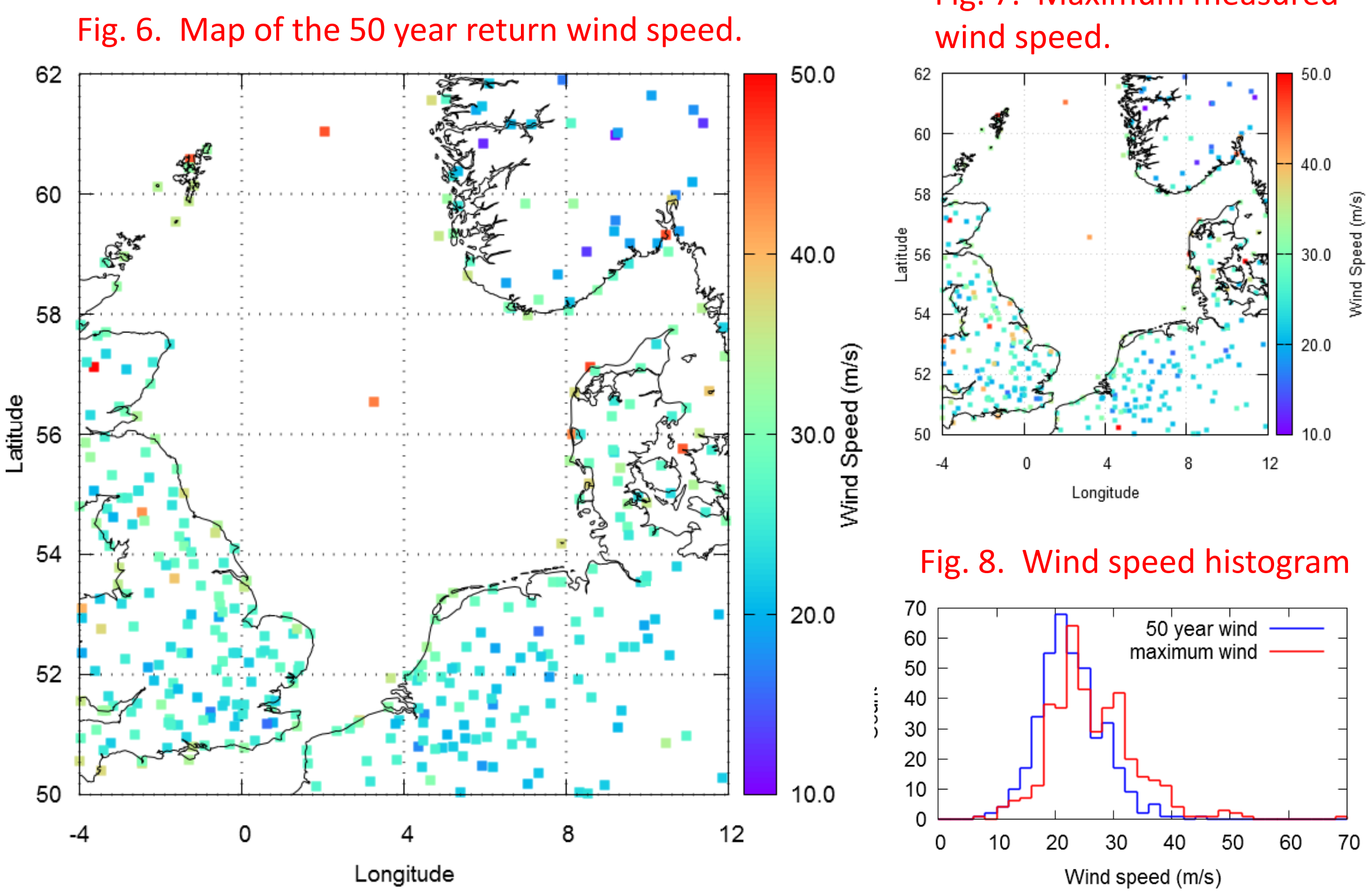Fig. 5. Wind speed histogram

Results:

The land stations in the USAF data set have good global coverage with only a few areas of sparse data in South America, Africa, and high latitude areas of Greenland and Antarctica (Fig 1-3). The number of years in the data sets varies from 20 years to >80 years, and the longest datasets are in North America and Eurasia (Fig 3, Fig 4). The 50 year return wind speed for most of the stations falls within the range 10–30 m/s, with some stations (mostly in coastal and offshore areas) showing extreme values >40 m/s (Fig 1, Fig 5).

The case study for the North Sea (Fig 6, Fig 8) highlights differences in the 50 year wind speed between the land stations (20-30 m/s) and offshore areas (>40 m/s). Worked examples of the wind speed return periods for selected stations in the North Sea are shown in Fig 10. These are based on the time series data in Fig 9, which highlights the interannual variability of the maximum wind speeds and also the data availability characteristics of the stations.

Case study: North Sea

Fig. 6. Map of the 50 year return wind speed.

Fig. 7. Maximum measured wind speed.

Fig. 8. Wind speed histogram

Worked Examples of Procedure

Fig. 9. Time series of maximum annual wind speed for 22 selected stations

Fig. 10. Maximum annual wind speeds versus Gumbel reduced variate

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