Was 2019/20 the dustiest year since 1944/45 in New South Wales

John Leys[1,3,4] Stephan Heidenreich[1], Stephen White[2], Juan Guerschman[4], and Craig Strong[3]
[1] Science Division, Department of Planning, Industry and Environment, Gunnedah, Australia
[2] Science Division, Department of Planning, Industry and Environment, Lidcombe, Australia
[3] Fenner School of Environment and Society, Australian National University, Canberra, Australia
[4] Land and Water – Black Mountain, CSIRO, Canberra, Australia

Email contact for the main author: johnleys58@outlook.com

Abstract

This paper reports if dust storms, an indicator of rangeland health, are becoming more or less frequent during droughts in New South Wales, Australia. This study compares the frequency of dust storms, i.e., when visibility is <1000 m, for three droughts: the recent 2017/20, Millennial and World War II droughts.

Dust records are not consistent over the last 80 years in Australia. We used two data sources, meteorological weather codes and DustWatch particulate matter <10-micron (PM10) data to create a time series of yearly dust storm days (DSD). The meteorological data records are coded as dust storms. The DustWatch data is PM10 concentrations and was acquired with two different types, 8520 and DRX, of DustTrak® instruments. A correction factor of one third was used to convert DRX to 8250 equivalent PM10. The hourly averaged PM10 concentrations were converted to visibility, using a regression equation, where an hourly averaged PM10 of >240 µg/m^3 was equal to a visibility of <1000 m, i.e., a dust storm.

Both data sets overlap in 2009/2010 which enabled calculation of DSD with both meteorological weather codes and DustWatch PM10 data. We then use the ratio of DSD in 2009/10 to 1944/45 and 2009/10 to 2019/20 to show that 1944/45 had 4.4 times more DSD than 2019/20.

One factor for the higher DSD for 2019/20 is that the area is protected from wind erosion. That is, the area with ground cover >50%, was 10% lower in NSW in 2019/20 (69% of the state) compared to 2009/10 (79%).

Introduction

The recurring question about dust storms and drought is “was it the biggest or worst”? It is a natural question to ask as dust storms and droughts are episodic and dust storms attract a great deal of media and public attention because they are spectacular phenomena.

Ranking drought is not the focus of this paper, rather the focus is on the frequency of dust storms. Meteorological observation records are the most widely used method for measurement of dust storm frequency, both in Australia Goudie (1983); O'Loingsigh *et al*. (2014) and elsewhere Goudie and Middleton (1992); Middleton and Goudie (2001); Novlan *et al*. (2007). Other methods include satellite imagery Prospero *et al*. (2002); Querol *et al*. (2019) and ground-based measurements with instruments Lei *et al*. (2016); Leys *et al*. (2018); Tong *et al*. (2012). Each method has strengths and weaknesses, for example, meteorological records have long time series but low daily frequencies of observation. Satellite imagery has good spatial coverage but limited temporal coverage.

To answer the question “was 2019/20 the dustiest year since 1944/45 in New South Wales”? we studied three droughts: World War II (1937/46) Millennial Drought (2001-10) and the

2017/20 drought. A mixture of Bureau of Meteorological (BoM) observation records and ground based particulate matter less than 10 µm (PM10) measurements from the DustWatch / Rural Air Quality network are used to count the frequency of dust storms for each dust storm year (DSY = July to June).

Methods

Dust storm frequency

We use the world meteorological organisation definition of a dust storm, i.e., when visibility is < 1000m. This is a long-standing definition that has been used to describe dust storm trends in space and time (Goudie 1983). There is no consistent data set for the last 80 years, so we use two data sources in this study. The BoM meteorological weather coded observations for the World War II and Millennial droughts as previously reported by O'Loingsigh *et al.* (2015). DustWatch hourly averaged PM10 readings for the later part of the Millennial drought and the 2017/20 drought. Data descriptions are detailed below.

Meteorological weather code data

We use the New South Wales (NSW) stations, of the Bureau of Meteorological (BoM) observations data set previously used by O'Loingsigh *et al*. (2015). There are seven weather codes which record dust storms, see Table 1 in O'Loingsigh *et al.* (2014). Weather observations are taken every three hours throughout the day and night, although this is not consistent across all stations. Two types of observations are taken: Present weather codes describe what is visible at the time of observation, and Past weather codes, which record all weather types since the last observation was taken at the station. The twelve stations used for 1944/45, 2009/10 are shown in Figure 1. Since some of the 1944/45 stations were discontinued, we use the closest station for the 2009/10 observations. We count dust storm days (DSD) as any day that has a dust storm code in the past or present weather code for a calendar date.

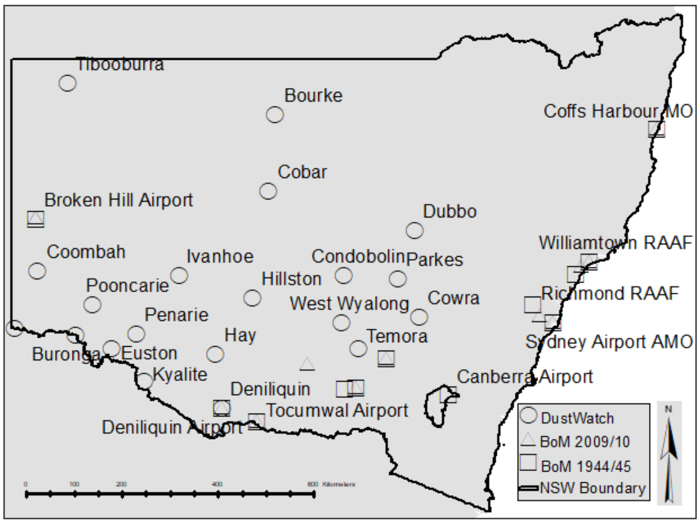

Figure 1 *Map showing locations of DustWatch and the Bureau of Meteorology (BoM) sites in 2009/10 and 1944/45.*

DustWatch / Rural Air Quality data

DustWatch began in 2005 and the Rural Air Quality Network commenced in 2017 and uses many of the original DustWatch sites. Twenty sites within NSW have been operational since

2007/08 and form the basis of the data used. Over the last three years the original 8520 models have been progressively replaced with DRX DustTrak® models.

We derived a conversion factor between 8520 and DRX PM10 measurements based on co-located instruments for one year, between September 2019 to 2020, at Coombah (Figure 1). For the analysis we only used dust aerosols, i.e., those aerosol readings with a PM2.5/10 ratio of less than 0.2. This ratio is lower than the 0.25 value of Koçak *et al.* (2007) as we wanted to be confident our samples are dust. This resulted in 463 hourly dust readings and a correction factor of DRX PM10μg/m^3 / 2.9383.

The Dust Trak® PM10 values were then converted to visibility. This is necessary as dust storms are classified by visibility, i.e., <1000 m. We use the same data source as Baddock *et al.* (2014), but instead of the instantaneous minute PM10 values we use the hourly average PM10 values. We acknowledge the limitation of comparing an hourly PM10 average value to an instantaneous visibility reading; however, this is the only data available.

$$V = 240 * PM10\hat{} - 0.98 \quad (1)$$

Where V = visibility in km, PM10 = DustTrak® 8520 concentration μg/m^3. Using Equation 1, a PM10 concentration of 240 μg/m^3 equates to a visibility of 1000 m. We then count dust storm days (DSD) as any calendar date when any hour in the day has a PM10 concentration greater than 240 μg/m^3.

Results

The count of the average DSD for each DSY is provided in Table 1. For the BoM weather observation data, 1944/45 is nearly ten times higher than 2009/10. For the DustWatch data, 2019/20 is about twice as high as 2009/10. This data suggests that 1944/45 had 4.4 times more DSD than 2019/20, thus making 1944/45 much dustier than the 2019/20.

Table 1. *Count of average Dust Storm Days (DSD) for each Dust Storm Year (DSY) and the ratio of DSD to 2009/10 for New South Wales sites. N is the number of observation sites*.

	1944/45	2009/10	2019/20	Ratio year to 2009
Ave DSD (BoM, N = 12)	5.8	0.6		9.9
Ave DSD (DustWatch N =20)		5.0	11.0	2.2

For any one station, the peak DSD count was 66 for Williamtown RAAF station in 1944/45, 10 for Broken Hill using Meteorological observations and 17 for Pooncarie using DustWatch data in 2009/10, and 31 for Coombah, south of Broken Hill, in 2019/20.

Satellite monitoring of total vegetation is available for the last 30 years via the RaPP Map web tool. Comparison of the area protected from wind erosion, i.e., the area with ground cover >50%, was 10% lower in NSW in 2019/20 (69% of state) compared to 2009/10 (79%).

Discussion

2019/20 was dustier than 2009/10 but less dusty than 1944/45 with 1944/45 having 4.4 times more DSD than 2019/20. This finding is similar to the national study of O'Loingsigh *et al*. (2015) who reported the WWII Drought was up to 4.6 times higher than during the

Millennium Drought. Total vegetation cover above 50% protects the soil from wind erosion. 2019/20 had 10% less area protected (69%) than 2009/10 (79%).

There are two competing drivers to dust storms, land management and climate. Land management practices have improved since the 1940s McTainsh *et al.* (2011) and this is mitigating the frequency of dust storms. Climate, however, is getting more extreme in terms of rainfall deficit and temperature increase. 2019 was the hottest and driest year on record Bureau of Meteorology (2020). Therefore, despite the extreme climate, land management has improved enough to reduce dust storms compared to 1944/45.

Conclusions

The challenge for this study is that dust records are not consistent over the last 80 years in Australia. This necessitated using two different data sources, meteorological weather codes and DustWatch PM10 data. The meteorological data has dust storm codes so is relatively easy to use, within the limitations of the observational frequency which change in space and time. The DustWatch data required two steps to get the DSD. First was the correlation between the new DustTrak® DRX with the older 8520 model. The DRX measures about three times the PM10 concentration of the 8520. Next was the conversion of the PM10 reading to visibility. Existing data used by Baddock *et al*. (2014) was used to get the hourly PM10 to visibility relationship. This indicated that an hourly averaged PM10 of >240 $\mu g/m^3$ was equal to a visibility of <1000 m, i.e., a dust storm.

Data for the three droughts could be expressed as DSD, with the data sets overlapping in 2009/2010. This enabled calculation of DSD with both meteorological weather codes and DustWatch PM10 data for that DSY. The ratio of DSD in 2009/10 to 1944/45 and 2009/10 to 2019/20 was calculated. The result was that for NSW, 1944/45 had 4.4 times more DSD than 2019/20.

References

Baddock, M.C., Strong, C.L., Leys, J.F., Heidenreich, S.K., Tews, E.K. and McTainsh, G.H. (2014). A visibility and total suspended dust relationship. *Atmospheric Environment* **89**, 329-36.

Bureau of Meteorology (2020). *Annual climate statement 2019*, Bureau of Meteorology, viewed 18 May 2020, www.bom.gov.au/climate/current/annual/aus/.

Goudie, A.S. (1983). 'Dust storms in space and time', *Progress in Physical Geography: Earth and Environment*: **7,** 4: 502-30.

Goudie, A.S., Middleton, N.J. (1992). The changing frequency of dust storms through time. *Climatic Change* **20**, 197-225.

Koçak, M., Mihalopoulos, N. and Kubilay, N. (2007). Contributions of natural sources to high PM10 and PM2.5 events in the eastern Mediterranean. *Atmospheric Environment* **41,** 18: 3806-18.

Lei, H., Wang, J.X.L., Tong, D.Q., Lee, P. (2016). Merged dust climatology in Phoenix, Arizona based on satellite and station data. *Climate Dynamics* **47**, 2785-2799.

Leys, J., Strong, C., Heidenreich, S., Koen, K. (2018). Where She Blows! A Ten-Year Dust Climatology of Western New South Wales Australia. *Geosciences* **8**, 232-247.

McTainsh, G., Leys, J., O'Loingsigh, T. and C., S. (2011). *Wind erosion and land management in Australia during 1940-1949 and 2000-2009.* Australian Government Department of Sustainability, Environment, Water, Population and Communities, Canberra.

Middleton, N.J., Goudie, A.S. (2001). Saharah dust: sources and trajectories. *Transactions of the Institute of British Geographers* **26**, 165-181.

Novlan, D.J., Hardiman, M., Gill, T.E. (2007) A synoptic climatology of blowing dust events in El Paso, Texas from 1932–2005. 16th Conference on Applied Climatology. American Meteorological Society, **J3**.12.

O'Loingsigh, T., McTainsh, G.H., Parsons, K., Strong, C.L., Shinkfield, P. and Tapper, N.J. (2015). Using meteorological observer data to compare wind erosion during two great droughts in eastern Australia; the World War II Drought (1937–1946) and the Millennium Drought (2001–2010). *Earth Surface Processes and Landforms* **40,** 1: 123-30.

O'Loingsigh, T., McTainsh, G.H., Tews, E.K., Strong, C.L., Leys, J.F., Shinkfield, P. and Tapper, N.J. (2014). The Dust Storm Index (DSI): A method for monitoring broadscale wind erosion using meteorological records. *Aeolian Research* **12**, 29-40.

Prospero, J.M., Ginoux, P., Torres, O., Nicholsan, S.E., Gill, T. (2002). Environmental characterisation of global sources of atmospheric soil dust identified with the NIMBUS-7 total ozone mapping spectrometer (TOMS) absorbing aerosol product. *Reviews of Geophysics* **40**, 2-1 - 2-31.

Querol, X., Tobías, A., Pérez, N., Karanasiou, A., Amato, F., Stafoggia, M., Pérez García-Pando, C., Ginoux, P., Forastiere, F., Gumy, S., Mudu, P., Alastuey, A. (2019). Monitoring the impact of desert dust outbreaks for air quality for health studies. *Environment International* **130**, 104867.

Tong, D.Q., Dan, M., Wang, T., Lee, P. (2012). ‘Long-term dust climatology in the western United States reconstructed from routine aerosol ground monitoring, Atmospheric Chemistry and Physics **12**, 5189-5205.