Discriminating accelerated from natural wind erosion at continental scale in Australia

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THIS PAPER

- Uses meteorological records to measure continent scale spatio-temporal patterns of wind erosion over 49 years (1960 - 2008).

- Explains these patterns in terms of two “natural” drivers; climate and sediment supply, and two land management drivers; grazing and mining.

Dust storm at Umuwa. Photo: Gary McWilliams, Mining Tenement Officer, APY
Background

Mapping wind erosion across a continent is challenging because:

- Scales of wind erosion processes can range from local events covering a few hectares and lasting a few minutes.

- To large dust storms traversing large sectors of the continent and lasting hours to days.

- *Local Dust event: Diamantina river floodplain, Queensland, Australia*

- *Dust storm eastern Australia: 23 Oct 2002*

- *Dust storm at Nappa Merrie station, SW Queensland. (Photo, Mark Coombe 2004. www.outbackpics.com)*
On-site impacts of wind erosion:

- Soil removal – infertile B horizon exposed by wind erosion.

- Reduction in soil fertility and moisture storage capacity in eroded dusts.
Off-site impacts of wind erosion:

- Reduced air quality in cities

![Brisbane Dust storm - December 1987](image1)

![Broken Hill - May 1994](image2)

- Offshore deposition contributes to marine sediments and deposits nutrients into the oceans

- Iron-rich dust may play an important role in fertilising the Southern Ocean. Boyd et al (2004) had a go but didn’t establish a relationship – a work in progress.

![Map of Australia](image3)

![Satellite image of dust](image4)
To better understand these on-site and off-site impacts more information is needed on WHERE, WHEN and HOW MUCH wind erosion occurs.

1. **Remote Sensing has gaps** (spatial and temporal), but provides valuable event-based data.
2. **Field-based Measurement techniques** are impractical for broad scale mapping.

Field dust sampling towers in the Channel Country, N.E. Lake Eyre Basin, Australia.
Bureau of Meteorology (BoM) records of “weather phenomena” provide data on wind erosion events across Australia.

06 = dust haze event (dust in suspension)
07 = local dust event (raised dust or sand)
08 = local dust event (Willy willy or dust devil)
09 = dust storm distant or in past hour
30 = moderate dust storm - decreased in past hour
31 = moderate dust storm - no change in past hour
32 = moderate dust storm - increased in past hour
33 = severe dust storm - decreased in past hour
34 = severe dust storm - no change in past hour
35 = severe dust storm - increased in past hour
98 = thunderstorm with dust storm

These records cover relatively long time periods - since 1960 (for ~110 stations), since 1942 (for ~ 25 stations) and archival records extend into C19.

These data are held in the Dust Event Database (DEDB) at Griffith University.
The DSI measures dust entrainment frequency and intensity.

Event intensity is measured using a composite measure of the contributions of: local dust events, moderate dust storms and severe dust storms using weightings for each event type, based upon visibility reduction for each event type.

\[ DSI = \sum_{i=1}^{n} [(5 \times SDS) + DS + (0.05 \times LDE)]_i \]

Where:
- DSI = Dust Storm Index at n stations where i is the ith value of n stations for i=1 to n.
- n = The total number of stations recording a dust event in the time period.
- SDS = Severe dust storm (daily maximum weather codes: 33, 34, 35)
- DS = Dust storm (daily maximum weather codes: 09, 30, 31, 32 and 98)
- LDE = Local dust event (daily maximum weather codes: 07 and 08)

Wind erosion (DSI) is highest in the driest part of the continent, but this relationship doesn’t apply in the WEST - why? (later)
2. **Temporal pattern** of wind erosion (1960-2008) – for the continent

Inter-annual variability is very high and is drought driven.

BUT averaging for the continent as a whole smooths out trends.
Spatio-temporal patterns of wind erosion in 5 time slices (1960-2008)
A quantitative spatio-temporal view can be gained by examining temporal trends in erosion in 4 major drainage regions which traverse the continent.
1. Temporal patterns of wind erosion (DSI) in the West, Centre and East are **driven by climate**

**WEST (Western Plateau & Indian Ocean)**

**CENTRE (Lake Eyre Basin)**

**EAST (Murray-Darling Basin)**

Rainfall in the West is driven by the *Indian Ocean Climate System* and in the East and Centre by the *Pacific Ocean Climate System*.
The rainfall-DSI relationship for the continent as a whole has a large data scatter.

*To what extent does this reflect “natural” drivers; climate and sediment supply and/or land management drivers; grazing and mining?*
Climate

There is a clear inverse relationship with rainfall, but what other aspects of climate (eg wind conditions) are driving wind erosion?

This issue can be resolved by correlating DSI with climate (rather than rainfall) – eg using the wind erosion climate index model of McTainsh et al., (1998).*

Sediment supply and land management effects can be examined by comparing the DSI-rainfall relationship in the 4 major drainage regions.

Two measures are used here:
1. Relative Erosion Rate (RER) (for 300 mm rainfall)
2. Erosion Response Curve (ERC) – the rate of erosion increases in response to decreasing rainfall
The rainfall-DSI relationship changes in the different drainage regions.

- **Indian Ocean (VII)**: $R^2 = 0.79$
- **Lake Eyre Basin (X)**: 1960-2008, $R^2 = 0.36$
- **Western Plateau (XI)** 1960-2008, $R^2 = 0.04$
- **Murray-Darling basin (IV)** 1960-2008, $R^2 = 0.56$
Erosion drivers:
- Climate - very similar (Pacific Ocean climate system – drought driven)
- Sediment supply - very similar (internally-draining rivers) but LEB is more active
- Land management – very similar (cattle grazing is widespread)

Erosion comparison:
- Relative Erosion Rate of LEB is ~1.6 times higher than MDB
- Erosion Response Curves are very similar
Sediment supply

Internally-draining rivers supply sediment to dust source areas in two (contrasting) ways:

1. Rivers feed silts and clays to:
   - Floodplains
   - Clay pans (playas)
   - Dry lake beds

2. Internally-draining rivers feed sands into dunefields (on geological timescales) - some of which are active dust sources (mainly the red dunefields).

The best developed (and reddest) dunefields in the LEB are fed by the Channel Country rivers. Birdsville (on the edge of the Simpson Desert) has the highest dust storm frequency in Australia.
Very high erosion at **Birdsville** is driven by *sediment supply* - on the edge of the Simpson Desert which has an additional dust entrainment process; clay skin abrasion

**Alice Springs** erosion was extremely high during the 1960s – due to *overgrazing*, but has decreased
Erosion comparison:

- Relative Erosion Rate of the WP is 50% of the LEB
- Erosion Response Curve of WP is much flatter than both LEB and MDB

Erosion drivers:

- Climate - very different (Indian Ocean climate system influences WP)
- Sediment supply - very different
- Land management - very different
Sediment Supply

The Western Plateau (WP) has *no organised river systems* - in contrast to the Lake Eyre Basin (LEB) and Murray-Darling Basins (MDB).

The absence of sediment supplying internally-draining rivers in WP reduces the number of active dust source areas and partly explains the low Relative Erosion Rate.
Land management - grazing
Rivers also control land management as surface water is needed to sustain pastoral properties.

There are no pastoral properties over large areas of the Western Plateau.

This region has indigenous protected areas.

Pattern of pastoral properties from a DustWatch survey.

Therefore there is less vegetation reduction from grazing in the Western Plateau which may partly explain the low wind erosion rates.

Is dust entrainment in the WP more “natural”?
Erosion hotspots at **Tennant Creek** and **Kalgoorlie** are associated with gold mining areas. **Ceduna** is on the edge of Eyre Peninsula – the only intensive agricultural area in the WP which has accelerated erosion.
Erosion comparison:
- Relative Erosion Rate of IO region is similar to the MDB
- Erosion Response Curve of IO is much steeper than all other regions

Erosion drivers:
- Climate – *similar to the WP* but different from LEB and MDB
- Sediment supply – *different from all*. Externally-draining river floodplains produce active erosion near the coast (e.g. Carnarvon)
- Land management – *very different* from all (grazing plus very intensive iron ore mining)
SUMMARY

- Temporal patterns of wind erosion differ between the WEST and EAST of the continent due to different oceanic climate drivers.

- Natural and land management drivers of erosion are discriminated by comparing the Relative Erosion Rate (RER) and Erosion Response Curves (ECR) of the 4 major drainage regions:
  - The Lake Eyre Basin is the most actively eroding region due mainly to active dust source areas supplied with sediments by internally-draining rivers
  - The Murray-Darling Basin has a lower RER but a very similar ERC, reflecting common erosion drivers
  - The Western Plateau has a very low RER and a flat ERC, reflecting the absence of internally-draining rivers, therefore: few dust source areas and no grazing, but erosion hotspots are associated with mining
  - The Indian Ocean region on the West Australian coast has a very steep ERC reflecting active erosion near the coast on externally-draining river floodplains and possibly land management impacts from intensive iron ore mining.