Kandakji et al. - Identifying and Characterizing dust point sources in the southwestern United States using remote sensing and GIS

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2/9/2021

Links from Nick

- Work with MODIS in R: https://www.earthdatascience.org/courses/earth-analytics/multispectral-remote-sensing-modis/modis-data-in-R/
- `MODIS` package in R: https://cran.r-project.org/web/packages/MODIS/MODIS.pdf

Links from the paper

- Tarek Kandakji OrcID: https://orcid.org/0000-0001-9173-5747
- Blowing dust paper: https://www.sciencedirect.com/science/article/pii/S0048969717328334?via%3Dihub
- Drought level and land use on dust: https://www.essoar.org/doi/10.1002/essoar.10500387.1
- 2021 paper: https://www.sciencedirect.com/science/article/pii/S0048969720359908
- The original paper: https://www.sciencedirect.com/science/article/pii/S0169555X19305100
- This file contains the location of the detected dust point sources: https://data.mendeley.com/datasets/6f8nyyr6n9/1

Figures

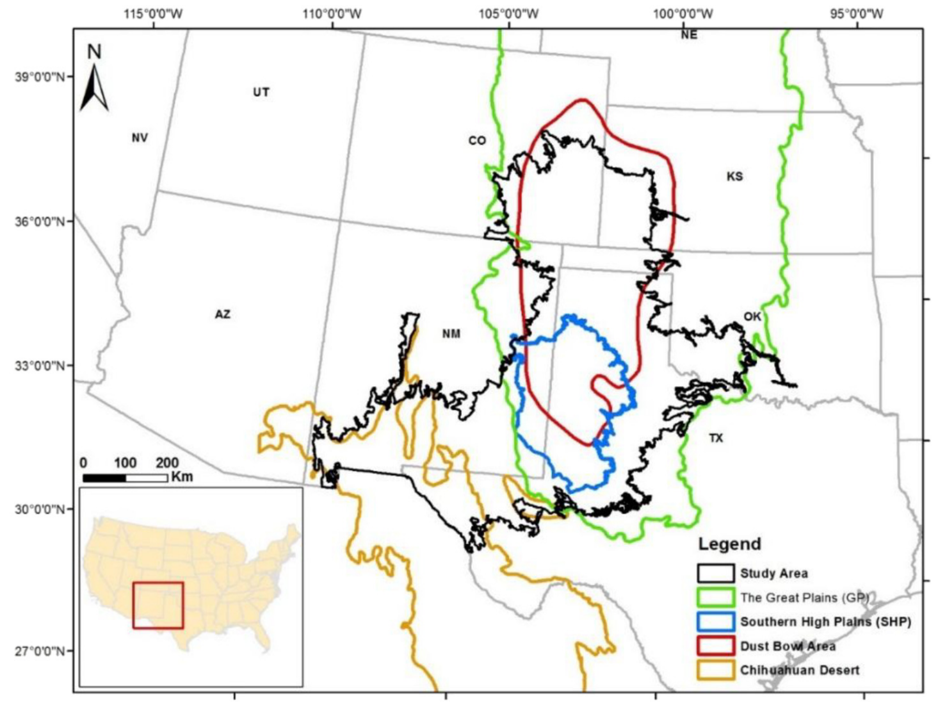

Figure 1: Study domain including key geographic regions discussed within the study.

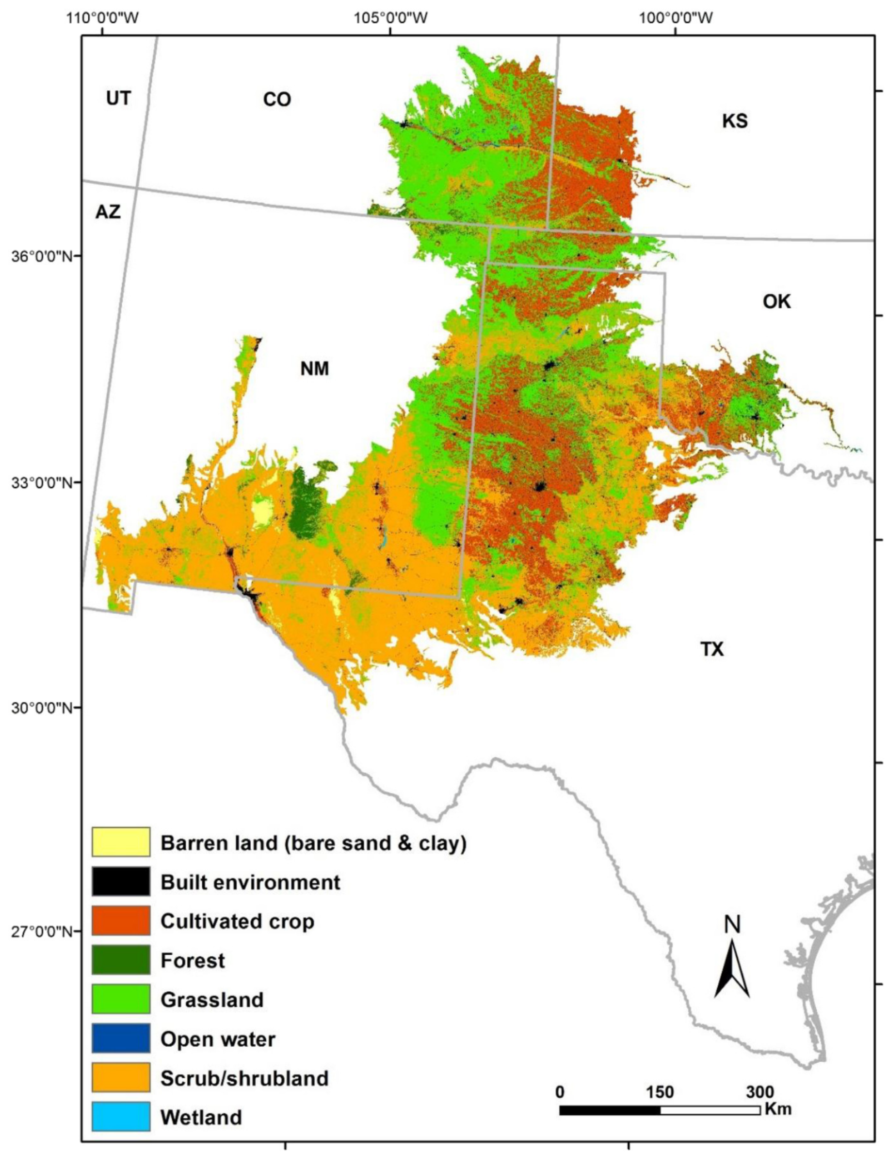

Figure 2: Land-cover map of the study domain for the year 2011. Data from Homer et al. (2015).

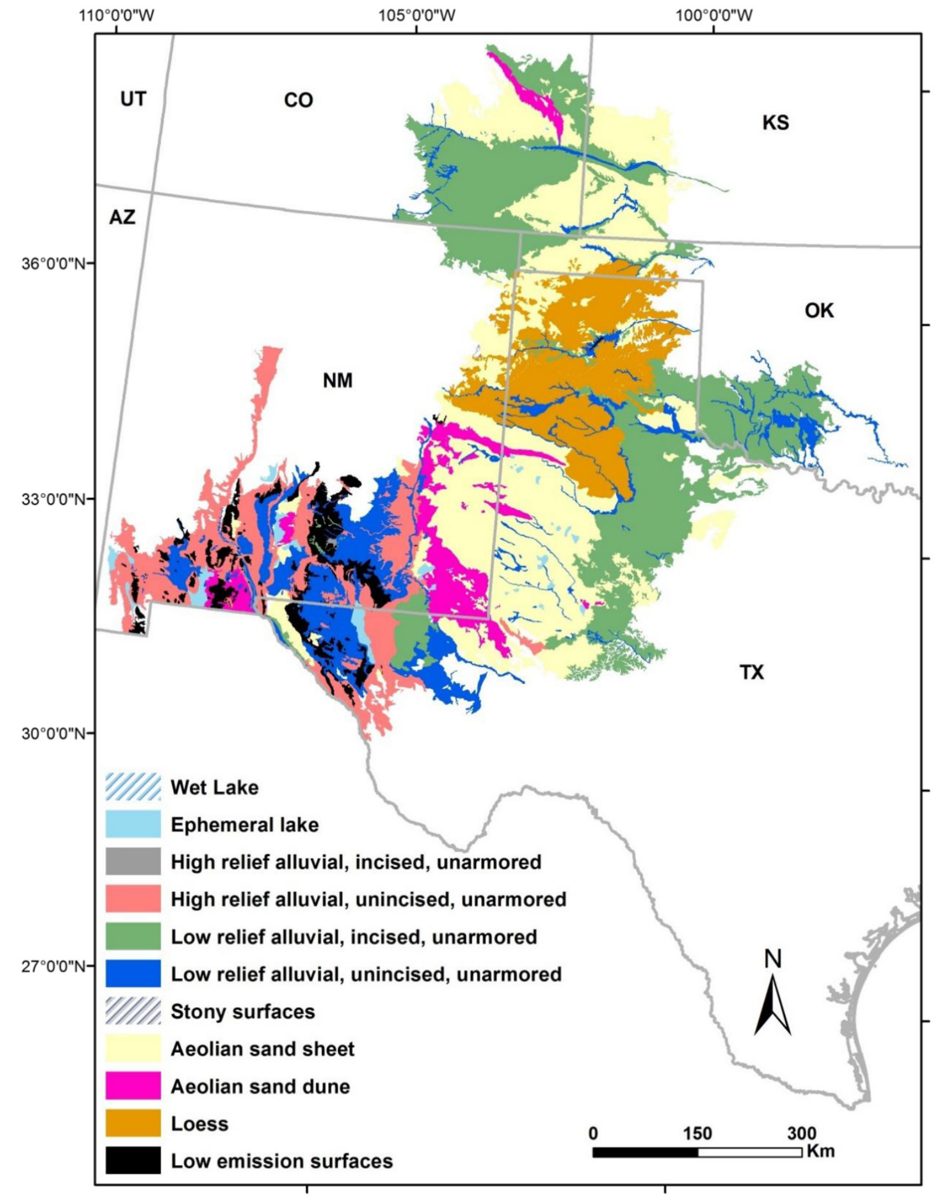

Figure 3: Geomorphology map of the domain, using the categories of Bullard et al. (2011) relating geomorphology to dust emission.

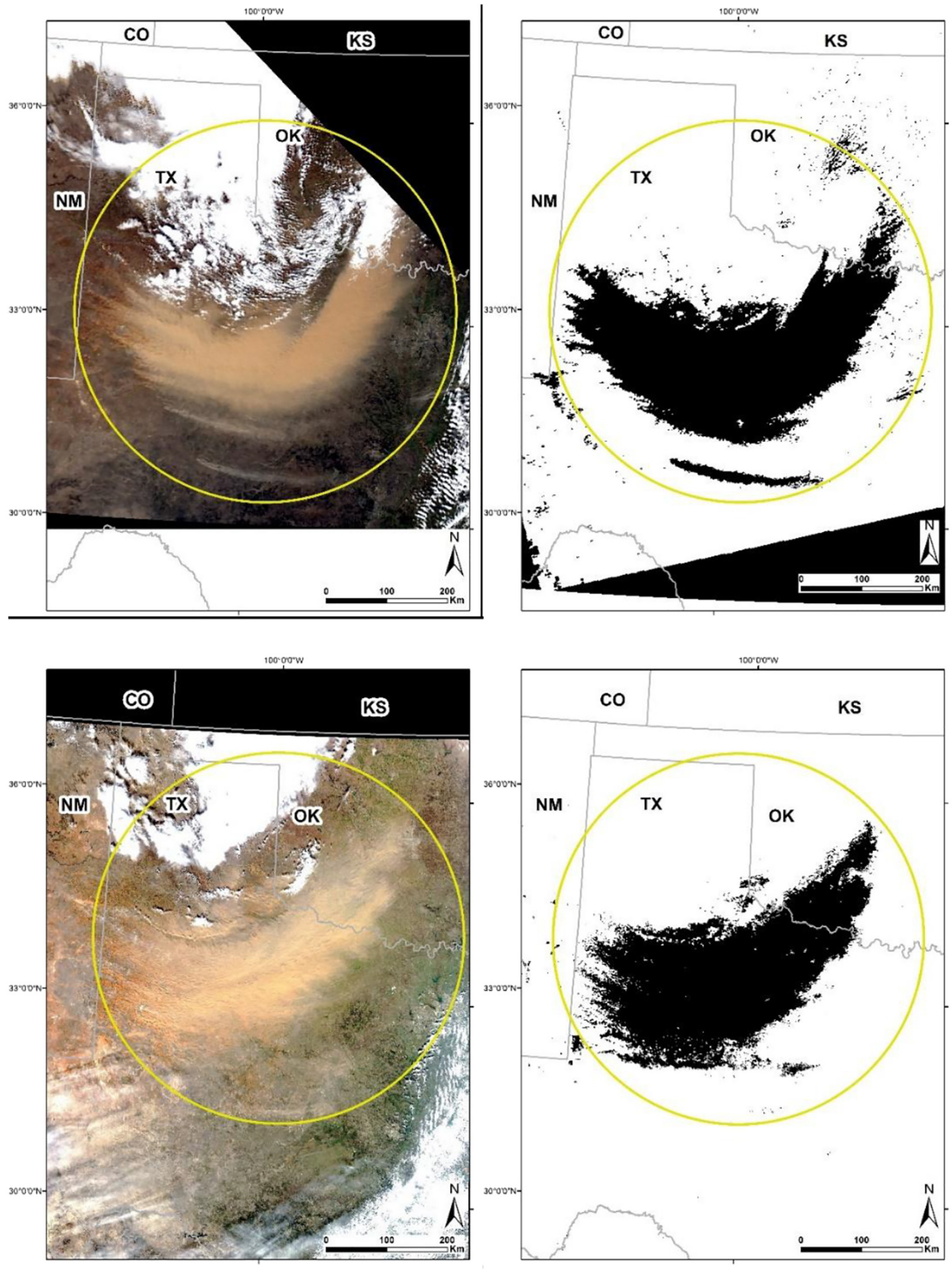

Figure 4: MODIS true color images (left) and their associated BTD images (right), for the days February 24, 2007 (top), and January 22, 2012 (bottom). The black color in the BTD images indicates dust.

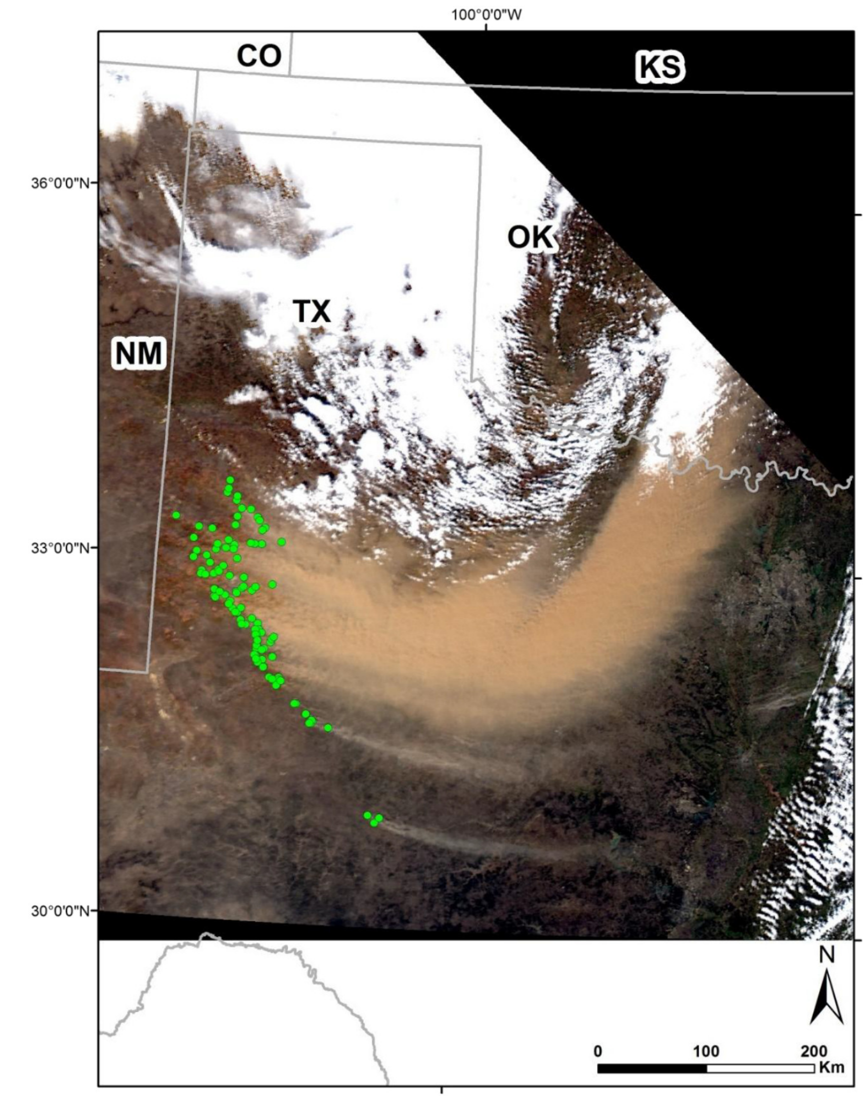

Figure 5: Dust source points identified for the dust event on February 24, 2007.

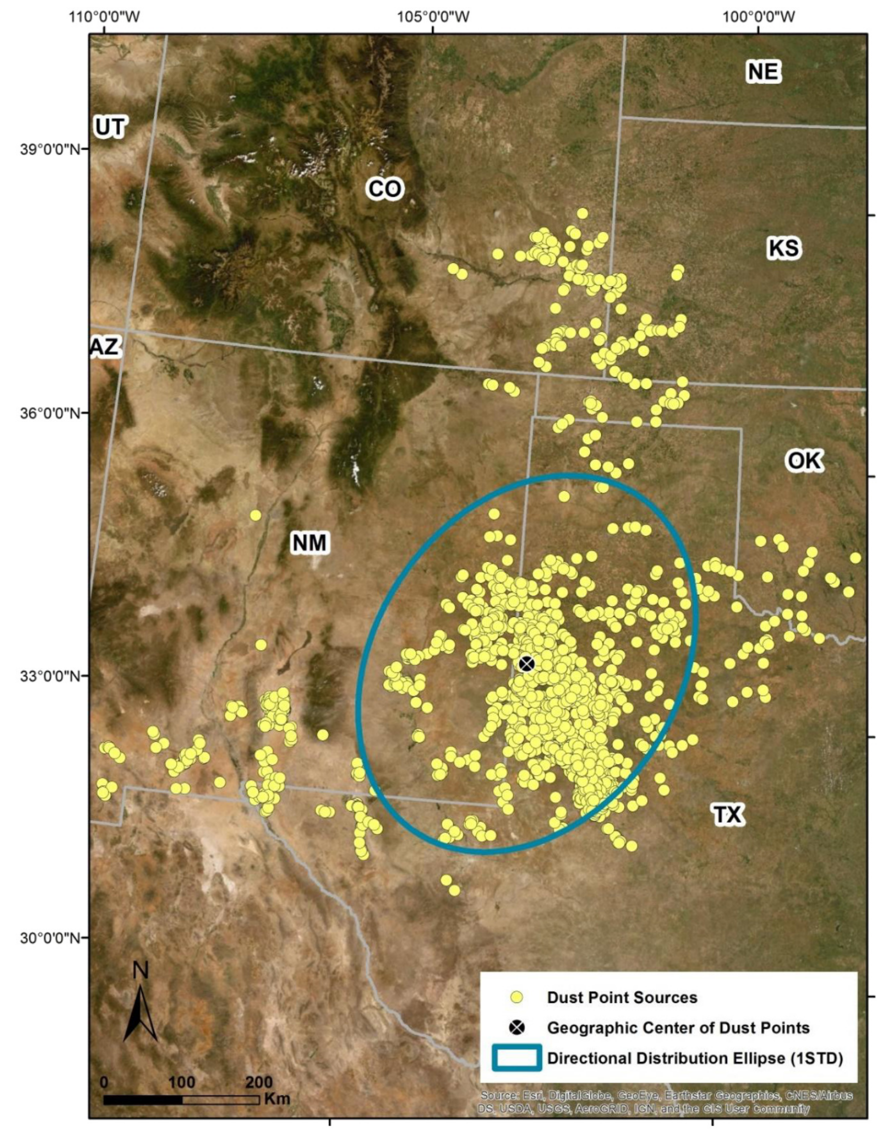

Figure 6: Mean center (geographic center) and directional distribution (Standard Deviation Ellipse) of all the dust points.

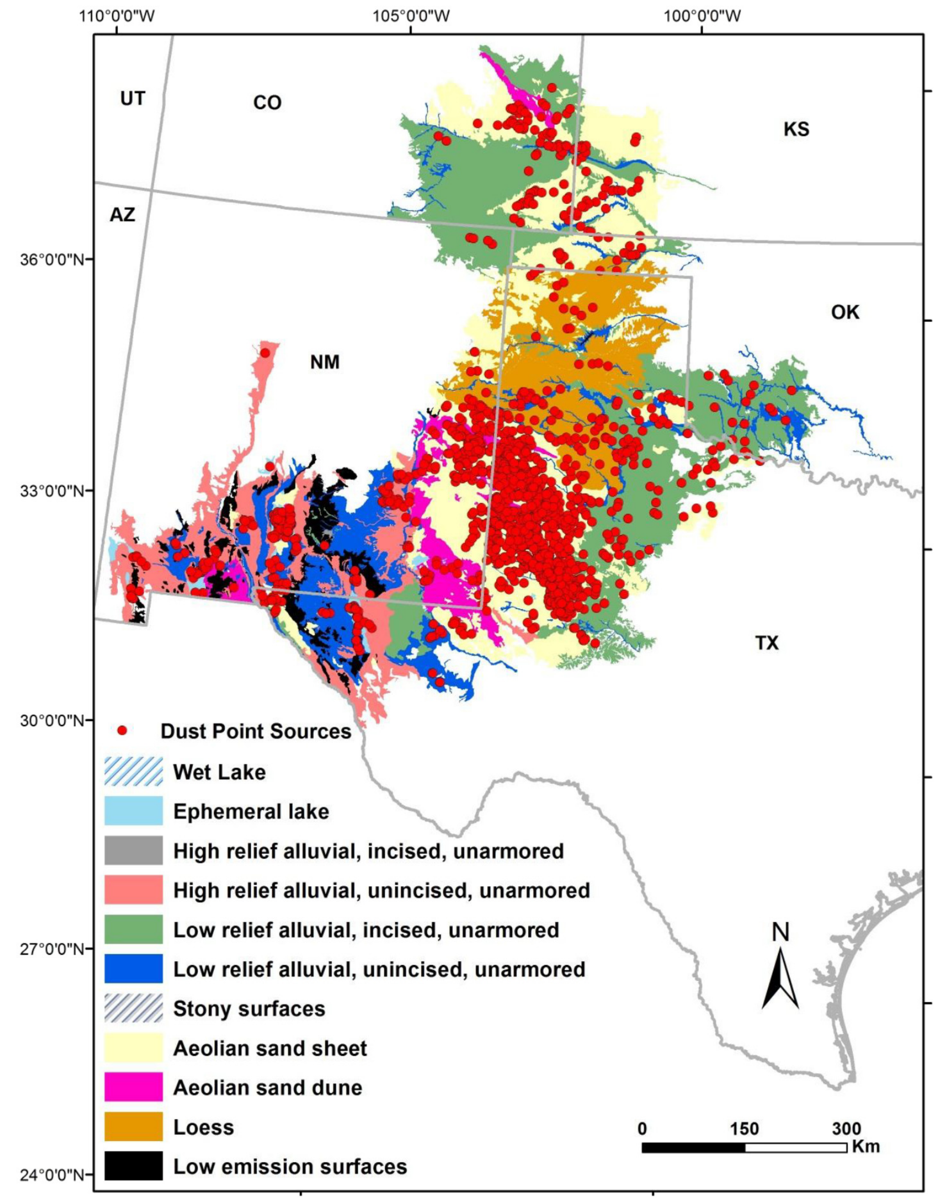

Figure 7: Identified dust source points (red dots) distributed over the geomorphic classes.

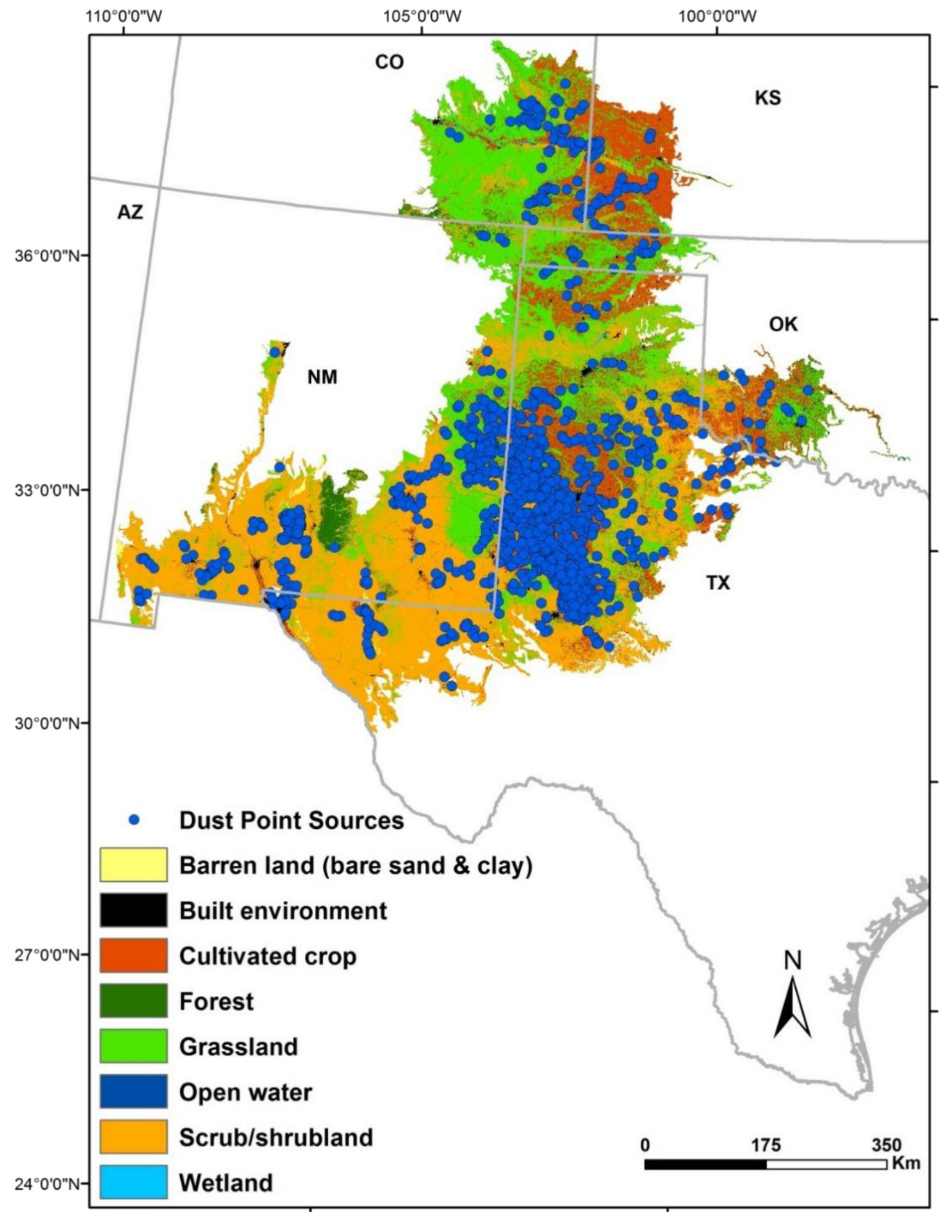

Figure 8: Identified dust source points distributed over the land-cover types of the study area.

Tables

Table 1. Weather stations used in the study.

```
# Suppress code because this:
# The mutate contains str_replace(.$"Long., Lat.", "-",
# last of which is an unprintable character (Unicode minus)
table_1 <- readxl::read_excel("Figures/Table-1.xlsx")

table_1 <- table_1 %>%
  rename(LongLat = 'Long., Lat.') %>%
  mutate(LongLat = str_replace(LongLat, "-", "-")) %>%
  extract(col = "Station name (station code)",
          into = c("Station_name", "Station_code"),
          regex = "(.+) \\((.+)\\)", remove = TRUE) %>%
  separate(col = LongLat, into = c("Longitude", "Latitude"),
         sep = ", ", remove = TRUE, convert = TRUE)
```

```
table_1
```

```
## # A tibble: 15 x 5
##    State      Station_name          Station_code Longitude Latitude
##    <chr>      <chr>                 <chr>            <dbl>    <dbl>
##  1 Colorado   Lamar                 LAA              -103.     38.1
##  2 Kansas     Dodge City            DDC              -100.     37.8
##  3 Kansas     Garden City           GCK              -101.     37.9
##  4 New Mexico Clovis                CVN              -103.     34.4
##  5 New Mexico Hobbs                 HOB              -103.     32.7
##  6 New Mexico Las Cruces            LRU              -107.     32.3
##  7 Oklahoma   Altus                 AXS               -99.3    34.7
##  8 Oklahoma   Altus Air Force Base  LTS               -99.3    34.7
##  9 Oklahoma   Elk City              ELK               -99.4    35.4
## 10 Oklahoma   Clinton-Sherman       CSM               -99.2    35.3
## 11 Oklahoma   Guymon                GUY              -102.     36.7
## 12 Texas      Amarillo              AMA              -102.     35.2
## 13 Texas      El Paso               ELP              -106.     31.8
## 14 Texas      Lubbock               LBB              -102.     33.7
## 15 Texas      Midland               MAF              -102.     31.9
```

Table 2. Summary of MODIS products used in the study.

```
table_2 <- readxl::read_excel("Figures/Table-2.xlsx")

table_2 <- table_2 %>%
  na_if(., "N/A") %>%
  separate(col = "MODIS product",
           into = c("MODIS_Terra_product", "MODIS_Aqua_product"),
           sep = " & ", remove = TRUE) %>%
  extract(col = "Bands", into = c("Band_number", "Band_name"),
          regex = "Band ([[:digit:]]+) \\((.+)\\)", remove = TRUE)
```

```
table_2
```

```
## # A tibble: 6 x 6
##   MODIS_Terra_pro~ MODIS_Aqua_prod~ Band_number Band_name Resolution Description
##   <chr>            <chr>            <chr>       <chr>     <chr>      <chr>
## 1 MOD09GA          MYD09GA          1           Red       500 m     Terra/Aqua~
## 2 MOD09GA          MYD09GA          3           Blue      500 m     Terra/Aqua~
## 3 MOD09GA          MYD09GA          4           Green     500 m     Terra/Aqua~
## 4 MOD21KM          MYD21KM          31          Thermal   1 km      Terra/Aqua~
## 5 MOD21KM          MYD21KM          32          Thermal   1 km      Terra/Aqua~
## 6 MOD03            MYD03            <NA>        <NA>      <NA>       Geolocatio~
```

Table 3. Summary of dust emission analysis by geomorphic class.

```r
table_3 <- readxl::read_excel("Figures/Table-3.xlsx")

table_3 <- table_3 %>%
  setNames(c("Geomorphology_class", "Area_km2", "Area_pct",
             "Dust_src_pts_n", "Dust_src_pts_pct",
             "Dust_Emission_Ratio_DER")) %>%
  na_if(., "-") %>%
  mutate(Subregion = ifelse(is.na(Geomorphology_class),
                            Geomorphology_class[-1],"Study Area")) %>%
  relocate(Subregion , .after = Geomorphology_class) %>%
  filter(!(Geomorphology_class %in%
             c("Great Plains", "Southern High Plains", "Chihuahuan Desert"))) %>%
  fill(Geomorphology_class, .direction = "down") %>%
  mutate(Area_pct = ifelse( Area_pct == "1.1000000000000001", "1.1", Area_pct)) %>%
  mutate(Area_pct = ifelse( Area_pct == "<0.1", "0", Area_pct)) %>%
  mutate(Area_pct = as.numeric(Area_pct)) %>%
  mutate(DER_comp = ifelse(Dust_src_pts_pct == 0, 0, Dust_src_pts_pct / Area_pct)) %>%
  mutate(DER_comp = ifelse(Subregion == "Study Area", NA, DER_comp))
```

```r
table_3
```

```
## # A tibble: 44 x 8
##    Geomorphology_c~ Subregion Area_km2 Area_pct Dust_src_pts_n Dust_src_pts_pct
##    <chr>            <chr>        <dbl>    <dbl>          <dbl>            <dbl>
##  1 Wet Lake         Study Ar~    290.       0.1              1              0.1
##  2 Wet Lake         Great Pl~    233.       0.1              1              0.1
##  3 Wet Lake         Southern~      0        0                0              0
##  4 Wet Lake         Chihuahu~     39.6      0                0              0
##  5 Ephemeral lake   Study Ar~   4956.       1.1            100              6.6
##  6 Ephemeral lake   Great Pl~    859        0.2             39              2.6
##  7 Ephemeral lake   Southern~    833.       0.2             39              2.6
##  8 Ephemeral lake   Chihuahu~   3462.       0.8             58              3.8
##  9 High relief all~ Study Ar~    194.       0                0              0
## 10 High relief all~ Great Pl~      0        0                0              0
## # ... with 34 more rows, and 2 more variables: Dust_Emission_Ratio_DER <dbl>,
## #   DER_comp <dbl>
```

Table 4. Summary of dust emission analysis by land cover type.

```
table_4 <- readxl::read_excel("Figures/Table-4.xlsx")

table_4 <- table_4 %>%
  setNames(c("Land_cover_type", "Area_km2", "Area_pct",
           "Dust_src_pts_n", "Dust_src_pts_pct",
           "Dust_Emission_Ratio_DER")) %>%
  na_if(., "-") %>%
  mutate(Subregion = ifelse(is.na(Land_cover_type),
                            Land_cover_type[-1],"Study Area")) %>%
  relocate(Subregion , .after = Land_cover_type) %>%
  filter(!(Land_cover_type %in%
            c("Great Plains", "Southern High Plains", "Chihuahuan Desert"))) %>%
  fill(Land_cover_type, .direction = "down") %>%
  mutate(Area_pct = ifelse( Area_pct == "2.2000000000000002", "2.2", Area_pct)) %>%
  mutate(Area_pct = ifelse( Area_pct == "20.399999999999999", "20.4", Area_pct)) %>%
  mutate(Area_pct = ifelse( Area_pct == "<0.1", "0", Area_pct)) %>%
  mutate(Area_pct = as.numeric(Area_pct)) %>%
  mutate(DER_comp = ifelse(Dust_src_pts_pct == 0, 0, Dust_src_pts_pct / Area_pct)) %>%
  mutate(DER_comp = ifelse(Area_pct == 0, NA, Dust_src_pts_pct / Area_pct)) %>%
  mutate(DER_comp = ifelse(Subregion == "Study Area", NA, DER_comp))

table_4
```

```
## # A tibble: 32 x 8
##    Land_cover_type Subregion Area_km2 Area_pct Dust_src_pts_n Dust_src_pts_pct
##    <chr>           <chr>        <dbl>    <dbl>          <dbl>            <dbl>
##  1 Open water      Study Ar~    861.       0.2              9              0.6
##  2 Open water      Great Pl~    735.       0.2              8              0.5
##  3 Open water      Southern~    172        0                6              0.4
##  4 Open water      Chihuahu~     35.9      0                0              0
##  5 Built environm~ Study Ar~  12493.       3.1             69              4.6
##  6 Built environm~ Great Pl~  10693.       2.6             66              4.4
##  7 Built environm~ Southern~   4048.       1               47              3.1
##  8 Built environm~ Chihuahu~   1123.       0.3              3              0.2
##  9 Barren land (b~ Study Ar~   3636.       0.9             91              6
## 10 Barren land (b~ Great Pl~    857.       0.2              9              0.6
## # ... with 22 more rows, and 2 more variables: Dust_Emission_Ratio_DER <dbl>,
## #   DER_comp <dbl>
```

Methodology

COMMENT: I think the order might have been 3.3 -> -> 3.4 -> 3.5 -> 3.1 -> 3.2, with the study area defined after they identified dust sources. The jagged borders of the black Study Area in Figure 1 seem to indicate this. Doing 3.3 first makes the most sense.

3.1 Land-cover map

"The data for the land-cover map (Fig. 2) were obtained from the National Land Cover Database (Homer et al., 2015) via their website: https://mrlc.gov. Maps for 2011 were used in this study."

3.2 Geomorphology

"A geomorphology map (Fig. 3) was created according to the dust source geomorphic classification adopted by Bullard et al. (2011). The classification was applied to a soil base map obtained from the USA Gridded Soil Survey Geographic (gSSURGO) Database State-tile Package (https://gdg.sc.egov.usda.gov/GDGOrder.aspx?order=QuickState)."

"The adjoining common polygons across each state's borders were unified. Based on the geomorphological information provided by the soil map, a geomorphic class from Bullard et al. (2011) was assigned to that polygon. The borders of the study area, however, were determined after the dust points were identified. The continuous outline of all polygons that included at least one dust point determined the border of the domain as shown in Fig. 1."

3.3 Weather data collection

"Weather data were collected from 15 meteorological stations located in five states: Colorado, Kansas, New Mexico, Oklahoma, and Texas, as were also used by Li et al. (2018) (Table 1). The data were obtained for the years 2011 to 2016 (https://mesonet.agron.iastate.edu/request/download.phtml)."

"Dusty days were determined following the procedure by Lee et al. (2012). A dust event was recorded if the visibility in one or more stations was less than 3 mi (~5km) for at least 1 h and the present weather code was indicating dust, or the weather code was dust for a minimum of 2h regardless of visibility."

"The METAR present weather codes (https://www.weather.gov/media/wrh/mesowest/metar_decode_key.pdf) that were considered as dust are: DS, DU, BLDU, DRSA, DS, PO, SA, SS, VCBLDU, VCDS, VCPO, and VCSS. Using the 2 mi visibility criterion or the 2 h dust reporting increase the probability that blowing dust is dense enough to be detected by the satellite imagery (Mahowald et al., 2003; She et al., 2018)"

3.4 MODIS data collection

"MODIS true color images were obtained from the University of Wisconsin Space Science and Engineering Center (SSEC) (http://ge.ssec.wisc.edu/modis-today/) and were examined visually prior to any analysis to detect visibility of dust plumes. Corrected MODIS true color images with 250 m spatial resolution were used. The website, however, has data available for dates after October 23, 2007. Moreover, some days after that date are missing from the website and not available. Subsequently, MODIS true color image for the missing dates were examined through the Level-1 and Atmosphere Archive & Distribution System (LAADS) Distributed Active Archive Center (DAAC) website (https://ladsweb.modaps.eosdis.nasa.gov/search/). For the missing days, true color images were created using the visible bands included in MODIS products MOD09GA and MYDO9GA, also obtained from LAADS."

"For each dusty day reported, the MODIS true color image for that day was examined to determine its suitability for analysis. Accordingly, if the image contained clouds over the dust source region and/or the dust plumes were identifiable, then that day was considered not suitable for image processing and thus excluded from the analysis (Lee et al., 2012)."

"After determining which dusty days had MODIS images suitable for analysis, certain MODIS products for that day were downloaded from the LAADS website. The products included are summarized in Table 2."

3.5 Image Processing

3.5.1 Producing MODIS true color images

3.5.2 Processing MODIS thermal bands

3.6 Identifying dust point sources

3.7 Calculating Dust Emission Ratio

3.8 Cluster analysis