AERO: a wind erosion modeling framework with applications to monitoring data

Brandon L. Edwards, Nicholas P. Webb, Sarah E. McCord

USDA-ARS Jornada Experimental Range, Las Cruces, NM, USA
What is AERO?

• The Aeolian Erosion Model (AERO) is an aeolian transport and dust emission modeling environment

• Developed to provide a decision-support tool for land managers in addition to a platform for basic research on aeolian processes

• Simulates size-resolved horizontal and vertical mass flux on the plot scale from user inputs of meteorological, soil and vegetation data

• AERO addresses the need for a generalizable wind erosion model that can be applied across different land cover settings
Motivation for development

- Non-standardized methods restrict analyses across US land use and management systems
- Field monitoring and research often use sampling designs that lack statistical rigor (frequently $n = 1$) and provide insufficient coverage for broad scale assessments
- Models not tested across land use and land cover types – model uncertainty unknown
- Clear need for a generalizable model with sufficient accuracy or precision that can leverage current monitoring data
Design considerations

• Generalizable - mechanistic

• Readily available/easily measured inputs

• Results applicable/meaningful on scales relevant to current management frameworks

Conceptual diagram of AERO model structure. AERO uses inputs of wind, soil and vegetation conditions to calculate horizontal and vertical mass flux.
Model design

Physically based models of aeolian transport inherently describe grain-scale processes

AERO calculates threshold friction velocity, horizontal flux and vertical flux at this scale over a distribution of grain sizes

Defaults/best methods:
Threshold: Iverson and White 1982
Horizontal flux: Gillette and Passi 1988
Vertical emission scheme: Shao 2011
Scaling up to the plot level?

AERO uses the Okin 2008 drag partitioning scheme based on vegetation structure to create a distribution of friction velocity values and associated probabilities for a plot.

When plot-level probabilities of friction velocity are combined with grain-scale threshold and flux probabilities, transport predictions are scaled upwards to plot-level.
March 2017, Jornada experimental range Wind Erosion Network site
Network Objectives:
Support research underpinning monitoring, models, and management

Improve availability of decision-support tools for managers/agencies

Facilitate collaboration to increase impact of science, planning and policy
Network standard methods protocol

Standardization of methods and data analysis is important for cross-site assessments of wind erosion controls and processes.
Model software structure: open source, customizable, flexible

• Coded in Python as a framework with separate modules for calculation methods
• Simulations can be run for a single set of conditions, time series of conditions, conditions over space, or a time series of conditions over space
• Selects available calculation methods depending on user selected order and suitability of inputs
• Key variables can be input as scalars, defined by descriptive statistics, supplied as probability distributions, or remote sensing-derived inputs and atmospheric data from the Weather Research and Forecasting (WRF) weather prediction model
Model inputs: core methods

• AERO was developed for compatibility with US Bureau of Land Management Assessment, Inventory and Monitoring (AIM) and National Resources Conservation Service National Resources Inventory (NRI) monitoring data collected using core methods

• Since 2003, the two programs have sampled at >50,000 locations using standardized methods consisting of 4 core indicators
Soil pits provide soil structure and surface soil texture information.

Line-point intercept provides fractional cover estimates.

Vegetation height measurements provide mean vegetation height for use in drag partitioning scheme.

Canopy gap measurements describe the distribution of vegetation/bare ground across plots.
Model inputs: meteorological conditions

• Observations
  • Compare specific plot-level scenarios across conditions

• Time series of observations
  • Event-based investigations

• PDF based on location
  • Regional assessments

• Spatial or WRF input
  • Regional scenarios with variable conditions, e.g. surface moisture
AERO implementation with NRI, LMF and AIM data

NRI, LMF, AIM Data

(DIMA, TerrADat)

Soil geodatabase providing parameters

Call atmospheric data by location

Model with user interface

Dust Flux (g/m²/s)

Horizontal Flux (g/m/s)

Provide user with estimates of sediment mass fluxes
Understanding differences in potential fluxes relative to management boundaries is important for identifying land use and management actions that could exacerbate dust emissions.
Management actions to benefit one resource may have negative consequences for other biotic and abiotic processes. In New Mexico, shrub removal treatments to benefit wildlife potentially increase dust emissions which could negatively impact regional air quality.
Variability among ecoregions and MLRAs

<table>
<thead>
<tr>
<th>Ecoregion</th>
<th>Total Horizontal Flux mean</th>
<th>Total Horizontal Flux sd</th>
<th>Total Dust Flux mean</th>
<th>Total Dust Flux sd</th>
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<tr>
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- MLRA 24 (25) is one of the most fire-susceptible MLRAs in the Great Basin.
- Heavy cheatgrass infestation following fire over the last 20 years.
- AERO run on 3,137 AIM plots enables assessment across Ecoregions and MLRAs, including fire effects.
In 2012 a 250,000 acre fire burnt in California
• Simultaneous severe drought
• BLM responded with drill and aerial seeding treatments to facilitate recovery
• AIM data were collected to monitor fire and treatment effects
Linking wind erosion to ecological sites
Benchmarks and management practices

Establish potential erosion rates for ecological sites and their respective states

Evaluate current erosion

Erosion > natural potential

Erosion < natural potential

Management/land use change

Erosion > natural potential

Erosion < natural potential

Assess risk of ecological state change

Manage:

- Loamy

Loamy

Persistent cover of vegetation

Low

High

Description of transitions:
1a – Overgrazing, soil fertility loss, erosion
2a – Shrub invasion due to overgrazing
3a – Shrub invasion; 3b – Shrub removal
4. Persistent reduction in grasses, compaction
5. Shrub removal

Frequency

% of plot with gaps > 100 cm
Where is development currently?

Progress:
Continuing to Build database of meteorological, vegetation and horizontal aeolian transport data for model calibration and refinement

Dust emission measurement capabilities are currently being added

Need:
Improve soil PSD database with representative samples from western US
Directions and goals

• Calibrate model using National Wind Erosion Network (https://winderosionnetwork.org) data

• Produce multi-scale wind erosion assessments (plot to national level) enabling regionalization of research and findings to support management

• Leverage large-scale ecological datasets to evaluate responses to management treatments and changes in land surface conditions

• Link model estimates to IMPROVE/AERONET data to interpret trends

• Incorporate wind erosion information into frameworks to support systems-level analyses of management co-benefits and trade-offs
AERO application to dust mitigation

• Which landscapes are emitting dust, how much, and when?
• How will management activities impact dust emission?
• How is air quality impacted by land condition and management?
• What are the costs, co-benefits and trade-offs for management practices and wind erosion mitigation options?