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Daily gridded weather for pesticide exposure modeling

Meridith M. Fry [a, *], Gabriel Rothman [a], Dirk F. Young [a], Nelson Thurman [a]

[a] US Environmental Protection Agency, Office of Pesticide Programs, Environmental Fate and Effects Division, 1200 Pennsylvania Ave, NW (7507P), Washington, DC 20460, USA

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ABSTRACT

Daily weather is compiled for pesticide exposure modeling from 1961 to 2014 at 0.25 × 0.25° latitude/longitude resolution for the United States using two National Oceanic and Atmospheric Administration (NOAA) products: National Center for Environmental Prediction Reanalysis and NOAA Climate Prediction Center Unified Rain Gauge Analysis. The compiled weather includes precipitation, temperature, wind speed, solar radiation, and reference evapotranspiration. Reference evapotranspiration is calculated using the Hargreaves-Samani method. Prior to this update, US pesticide exposure models relied upon the Solar and Meteorological Surface Observation Network dataset, which provides the same variables but only from 1961 to 1990 for 237 US weather stations. More extensive (1961–2014), spatially-resolved weather allows for more robust estimates of time-averaged pesticide concentrations for assessing acute and chronic exposure to pesticides. Continued expansion of the weather dataset is planned as the latest data is released. Processed weather for pesticide exposure modeling will be publicly available from the US EPA.

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1. Introduction

Historical weather data is frequently the dominant driver in modeling chemical fate and transport in the natural environment. Weather parameters (e.g., rainfall, evaporation, wind, temperature) highly influence a chemical's movement through land, water, and air (Thibodeaux, 1996; Wauchope, 1978). Additionally, the temporal and spatial resolution of chemical fate and transport models are directly dependent on the resolution of the weather input data. As a result, the development of weather inputs is critical to providing up-to-date, realistic, and appropriate modeling results (Mineter et al., 2003).

Weather is particularly important in regulatory pesticide exposure models when a chemical is applied directly to an exposed natural environment. Precipitation and evapotranspiration are the dominant parameters in estimating runoff, erosion, and leaching amounts. Air temperature and solar radiation are critical for estimating soil and water body temperatures, which in turn influence chemical degradation rates. Wind speed and temperature are also drivers for the volatilization and aerial deposition of chemicals (Young and Fry, 2014).

The availability of these weather parameters also dictates the temporal and spatial resolution of regulatory pesticide exposure models. Model results are only meaningful at time steps no shorter than the weather time steps provided. For example, daily flows that may drive chemical transport cannot be accurately estimated if only monthly-averaged precipitation is available as an input. In the absence of daily weather time series, some pesticide models have built-in weather generators to derive synthetic daily weather from long-term averages (Jarvis et al., 1997). Pesticide exposure models also require both short- and long-term weather data time series in order to estimate both acute and chronic exposure concentrations. Estimated exposure concentrations are especially sensitive to the timing of pesticide applications with respect to rainfall events (Wauchope, 1978).

Modeled outputs are also limited by how well weather data represents the land area being modeled. Some pesticide models developed for individual catchments use weather data from point weather station locations (Holvoet et al., 2005, 2008). In this context, the model's spatial resolution is only as fine as the distance between weather data points. More recent advances, however, support the use of interpolated (gridded) weather data for spatially continuous inputs over large areas, and likewise model outputs at refined spatial and temporal scales (Mineter et al., 2003).

For US pesticide exposure models, weather inputs are needed across the US at daily frequency and over a sufficiently long period of time to account for both the day-to-day changes and central tendency of weather. According to the World Meteorological

* Corresponding author.
E-mail address: fry.meridith@epa.gov (M.M. Fry).

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Data availability

Name: Daily weather for US pesticide exposure modeling
Developer: Meridith M. Fry (fry.meridith@epa.gov)
Address: 1200 Pennsylvania Ave, NW (7507P), Washington, DC USA 20460
Format: CSV
Availability: Public
Cost: Free

Organization (WMO) and the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center (NCDC), 30 years of weather typically represents the average pattern of weather (climate) for a particular location while also capturing daily weather anomalies or extremes (Arguez et al., 2012; Solomon et al., 2007). Using a greater number of years of weather also allows for an increased number of daily estimated exposure concentrations, which can be used to generate more robust summary statistics and time-averaged concentrations.

Two recent gridded weather products are available which suit the temporal and spatial needs of US pesticide exposure models. The first dataset from the NOAA National Center for Environmental Prediction (NCEP) and National Center for Atmospheric Research (NCAR) Reanalysis offers national coverage of the required daily weather variables from 1/1/1948 to present day at 2.5 × 2.5° longitude/latitude resolution. A second dataset, the NOAA Climate Prediction Center (CPC) Unified Rain Gauge Analysis, provides daily precipitation over the same time period (1/1/1948 to present) and at an even finer grid resolution (0.25 × 0.25° latitude/longitude) across the US. These data are a vast improvement over the previous weather data used in US pesticide exposure models, namely the Solar and Meteorological Surface Observation Network (SAMSON) dataset (Burns et al., 2007).

The SAMSON dataset has been the primary weather data used in the US regulatory pesticide exposure models since the early 1990s and has been deemed in need of updating with more recent data by US EPA Scientific Advisory Panels (FIFRA SAP, 2010). SAMSON spans the dates 1/1/1961 to 12/31/1990 for 237 National Weather Service (NWS) weather station locations in the US. The SAMSON dataset was originally developed by the NOAA NCDC and the National Exposure Research Laboratory (NERL) of the US EPA, based on both observations and modeled results (Burns et al., 2007). Current US pesticide exposure models: US EPA Pesticide in Root Zone Model (PRZM5) and Variable Volume Water Model (VVWM) (Young and Fry, 2014; Young, 2014), which have historically used SAMSON data, are well adapted to take advantage of this new weather dataset. The compiled weather also provides model users with the ability to run simulations for a greater number of years or a subset of more recent years. This paper describes the methods used to develop the new weather dataset and provides an evaluation of its use in PRZM5 and VVWM.

2. Methods

The presented weather dataset is collated daily from 1/1/1961 to 12/31/2014 with over 27,800 grid points uniformly covering the lower 48 US (20–49.5°N, 233.75–292.75°E). Daily values for temperature, wind speed, solar radiation, and reference evapotranspiration (ET_o) based on the NOAA NCEP/NCAR Reanalysis dataset (2.5 × 2.5° resolution globally) are combined with daily precipitation from the NOAA CPC Unified Rain Gage Analysis (0.25 × 0.25° resolution over the US). Both native datasets are actively maintained by NOAA and continually extended to present day. Therefore, the compiled dataset can be expanded with the most recent NCEP/NCAR and CPC daily values as they become available.

Two NOAA products: 1) NOAA NCEP/NCAR Reanalysis, and 2) NOAA CPC Unified Rain Gauge Analysis were accessed online and downloaded in network common data form (netCDF) for the years 1961 through 2014. The native spatial extent of the NOAA NCEP/NCAR Reanalysis is global, while the NOAA CPC Unified Rain Gauge Analysis extent is the continental US. Table 1 includes a list of the variables downloaded from each source.

NOAA NCEP/NCAR Reanalysis variables: temperature (daily mean, maximum, and minimum), wind speed (u-wind and v-wind), and downward solar radiation (at surface and nominal top of the atmosphere) were extracted for the continental US from the global extent and interpolated from their native 2.5 × 2.5° rectilinear grid to the fine 0.25 × 0.25° rectilinear grid of the CPC precipitation using bilinear interpolation from the NCAR Command Language (NCL) linint2 function (NCL, 2015). The bilinear interpolation is first performed in the x direction, followed by the y direction. This single interpolation scheme is applied uniformly across the lower 48 US grid cells for consistency and to limit any data voids.

The five variables: precipitation, ET_o, temperature, wind speed, and solar radiation are compiled for all years on a daily frequency over a common grid (0.25 × 0.25° latitude/longitude). Table 2 summarizes the unit conversions performed for each variable during compilation. Appendix A presents an example compiled file.

Because ET_o is not directly available from the NOAA NCEP/NCAR and NOAA CPC datasets, it is the one calculated parameter in the compiled weather dataset. ET_o is calculated following the bilinear interpolation of the NOAA NCEP/NCAR Reanalysis input variables. The previous SAMSON dataset provided pan evaporation, and US models (PRZM5, VVWM) estimated ET_o from US Weather Bureau pan coefficients (Carousel et al., 2005). Although many of the same factors that influence crop reference evapotranspiration also affect pan evaporation, there are differences in the evaporation from an

Table 1
Weather variables from NOAA NCEP/NCAR Reanalysis and NOAA CPC Unified Rain Gauge Analysis.

NOAA NCEP/NCAR Reanalysis (Global)
Surface fluxes (daily from 1961 to 2014)[a]:
Mean air temperature at 2 m
Maximum air temperature at 2 m
Minimum air temperature at 2 m
U-wind at 10 m[b]
V-wind at 10 m[c]
Downward solar radiation at surface
Other fluxes (daily from 1961 to 2014)[d]:
Downward solar radiation at nominal top of the atmosphere
NOAA CPC Unified Rain Gauge Analysis (US)
Surface (daily total from 1961 to 2014)[e]:
Precipitation

[a] NCEP Reanalysis data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their website at http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.surfaceflux.html, Last accessed: 14 Jan 2016

[b] U-wind represents zonal component of vector wind speed at 10 m above the surface; sign convention: positive u winds blow from west (westerlies).

[c] V-wind represents meridional component of vector wind speed at 10 m above the surface; sign convention: positive v winds blow from south (southerlies).

[d] NCEP Reanalysis data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their website at. http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.other_flux.html, Last accessed: 14 Jan 2016

[e] CPC US Unified Precipitation data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their websites at http://www.esrl.noaa.gov/psd/data/gridded/data.unified.daily.conus.html (1984 – 2006), Last accessed: 14 Jan 2016; http://www.esrl.noaa.gov/psd/data/gridded/data.unified.daily.conus.rt.html (2007 – 2014), Last accessed: 14 Jan 2016