Surface Dust Flux Model
Functional Requirements

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1 Overview

1.1 *Overview*

This document describes the Surface Dust Flux modeling software package. The model uses MM5 forecasted surface winds to estimate the rate at which ground level dust is being produced from source areas within a mesoscale theater. Surface dust fluxes vary in desert regions from 10 –100 μgm/m^2-s for small to moderate fluxes, and 500 to 2000 μgm/m^2-s or more under dust storm conditions.

The model uses MM5 forecasted wind fields, estimated precipitation as input. As a proxy for soil moisture, precipitation data is used to suppress dust generation where there has been significant rainfall. The dust flux is calculated at each MM5 model grid location (~45 km intervals) in the mesoscale theater. The flux is calculated using forecasted 10 meter wind speeds and the dust source database model developed by Dr. Paul Ginoux at NASA GSFC/GIT.

The dust model can make forecasts for 2 MM5 mesoscale regions covering Northern Africa and the Middle East (T9z) and Southwest Asia (T4y). The surface dust fluxes are displayed as regional maps with color overlays showing dust fluxes in μgm/m^2-s. The user should note that this model does not forecast the transport of dust in the atmosphere or local dust concentrations. It only makes a prediction of the rate at which dust is generated at the surface.

1.2 *Statement of Purpose*

The Surface Dust Flux model has been created as a forecasting and analysis tool to predict the rate at which surface dust is produced in desert regions. The model estimates the rate as a dust flux, calculated in μgm/m^2-s from the surface. The model estimates surface fluxes for 4 particle sizes groups: 0.1 to 1.0 μm, 1.0-1.8 μm, 1.8-3.0 μm and 3.0 to 6μm.

Features of the dust flux model are the inclusion of a new dust source model based on research work by Paul Ginoux, Professor Joseph Prospero and Mian Chin (*Ginoux et al. 2000, Prospero et al. 2002, Chin et al. 2001*). The dust source model is unique in that it uses a global dust database based on terrain elevation data in desert regions to identify topographic depressions that are key dust source areas. The Ginoux dust source model included with this software package is based on the 1°x1° resolution dataset, re-interpolated to each MM5 mesoscale theater grid point at roughly 1/2° intervals. The Ginoux source model has been verified and supplemented using satellite and ground observations. It is currently undergoing continuing research to generate a higher resolution 10kmx10km global model.

The surface dust fluxes are are driven by the forecasted MM5 windfields at 10 meter heights. The dust flux is calculated based on a calculated wind threshold velocity, $\boldsymbol{u_t}$ for each particle diameter $\Phi_{p.}$ The threshold velocity is calculated using:

$$u_t = A*\sqrt{(\rho_p-\rho_a/\rho_a\ g\ \Phi_p)}*1.2+0.2\log_{10} w \quad \text{if } w < 0.5$$
$$\infty \quad \text{otherwise}$$

where g is the acceleration of gravity, ρ_p and ρ_a are the dust particle and air density. The model uses precipitation to vary the surface soil wetness *w*, which varies from 0.01 to 1. Dust fluxes are reduced in source areas as the soil wetness approaches 0.5. Above a soil wetness of 0.5, the dust flux is assumed to be zero where the wind threshold velocity becomes infinite. In desert regions under arid conditions, *w* varies from 0.01 to 0.1. If soil moisture and precipitation are not used in the Surface Dust Flux Model (SDFM), *w* is set to a default value of 0.1 for arid regions. Note that in the first version of SDFM, *w* is set to the default value for arid regions. The surface dust flux is calculated for each particle size class using:

$$F_p = C * S * s_p\ u^2_{10m}(u_{10m} - u_t) \ \text{if} \ u_{10m} > u_t$$
$$0 \ \text{otherwise}$$

F_p is the surface dust flux in $\mu g/m^2$-s, C is a dimensional constant equal to 1 $\mu gm\ s^2 m^{-5}$, and S is the Ginoux dust source value at the MM5 grid point. The surface wind velocity is taken at 10 meters. Future versions of this model will use the surface friction velocity to calculate dust fluxes when available in MM5 data files.

2 SDFM Process

2.1 Functional Requirements

The SFDM Process shall use MM5 daily weather forecast data to generate maps showing mesoscale surface dust fluxes at 3 hour forecast intervals.

2.1.1 The SDFM Process shall automatically process MM5 gridded binary weather data in AFWA grib format in mesoscale theaters 4 and 9.

2.1.2 The SDFM will process 24 consecutive MM5 weather forecast data files. The files shall be at 3 hour forecast intervals. medians are evaluated for data points falling in the window using a sorting routine.

2.1.3 The SDFM Process shall generate color maps showing the surface dust emission. The maps will be colorized using red for high or severe levels of surface dust (dust storm conditions), yellow for moderate obscuration conditions from surface dust and green to show nominal or low levels of emission. Non colorized map areas will represent normal dust aerosol levels free of ground source emission

2.1.4 The Surface Dust Flux Process shall store the flux emission maps as GIF images. The maps will use color overlays showing the surface dust flux in µgm/m2-sec.

2.2 Interface Requirements

Input Interfaces

2.2.1 The Surface Dust Flux Model Process shall ingest the MM5 data. The format of these flat files are listing in the following reference:

C. H. Dey. GRIB, Edition 1, NCEP Central Operations, National Weather Service, NOAA, U.S. Dept. of Commerce, Office Note 388, 1998.

Output Interfaces

2.2.2 The Surface Dust Flux Model Process shall write the SDFM GIF output file described in Section 2.1.8. This file is written to a user-defined output directory.

User Interfaces

2.2.3 The Surface Dust Flux Model Process shall accept MM5 Data and analysis parameters entered by the user via a GUI interface.

2.3 Operational Requirement

2.3.1 The Surface Dust Flux Model Process shall run under the Solaris operating system.

2.3.2 The Surface Dust Flux Model Process shall begin execution upon direction of the user.

3 References

Dey, Clifford H., The WMO Format for the Storage of Weather Product Information and the Exchange of Weather Product Messages in Gridded Binary Form as used by NCEP Central Operations.

Chin, M., Ginoux, P., Kinne, S., Torres, O. Holben, B. Duncan, et al., Tropospheric aerosol optical thickness from the GOCART model and comparisons with satellite and sunphotometer measurements, J. Atmos. Sci. June 2001.

Ginoux, P. Chin, M., Tegen, J., Pospero, B. Holben, O. Dubovik and S. J. Lin, 2001, Sources and global distributions of dust aerosols simulated with the GOCART model, J. Geophys. Res., 106, 24,698-24712.

Prospero, J., P. Ginoux, O. Torres, S. Nicholoson and T. E. Gill, Environmental characterization of global sources of atmospheric soil dust identified with the imbus 7 total ozone mapping spectrometer (TOMS) absorbing aerosol product, Reviews of Geophysics, 40, 1, February 2002.

4 Acronyms and Abbreviations

Acronym	Definition
AACGM	Attitude Adjusted Corrected Geomagnetic
AFCCC	Air Force Combat Climatology Center
AFOSR	Air Force Office of Scientific Research
AFRL	Air Force Research Laboratory
AFSCN	Air Force Satellite Control Network
AFSPACECOM	Air Force Space Command
AFSWC	Air Force Space Weather Center
AFWA	Air Force Weather Agency
AFWIN	Air Force Weather Information Network
AF/XOW	Air Force Director of Weather
APL	Applied Physics Laboratory of Johns Hopkins University
ASCII	American Standard Code for Information Interchange
ASPAM	Atmospheric Slant Path Analysis Model
AVHRR	Advanced Very High Resolution Radiometer
AVN	Aviation Model
AVO	Alaska Volcano Observatory
BATS	Biosphere-Atmosphere Transfer Scheme
CLASS	Canadian Land Surface Scheme
COE	Common Operating Environment
DII	Defense Information Infrastructure
DMSP	Defense Meteorological Satellite Program
ECMWF	European Center for Medium-Range Weather Forecasts
FAC	Field Aligned Currents
FNMOC	Fleet Numerical Meteorology and Oceanography Center
FSL	Forecast Systems Laboratory
FTP	File Transfer Protocol
GI	Geophysical Institute
GIC	Ground Induced Currents
GIF	Graphic Interchange Format
GIT	Georgia Institute of Technology
GMT	Generic Mapping Tools
GOLD	Geophysical On-Line Data
GRIB	Gridded Binary
GSFC	Goddard Space Flight Center
HLBL	High Latitude Boundary Layer
IDL	Interactive Data Language
IMF	Interplanetary Magnetic Field
JHU	Johns Hopkins University
LAN	Local Area Network

LAPS	Local Analysis and Prediction System
LSM	Land Surface Model
MM5	Fifth Generation Mesoscale Model
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
netCDF	Network Common Data Form
NGDC	National Geophysical Data Center
NGM	Nested Grid Forecast Model
NOGAPS	Navy Operational Global Atmospheric Prediction System
NWP	Numerical Weather Prediction
OWS	Operational Weather Squadron
PACE	Poloar Anglo-American Conjugate Experiment
PBL	Planetary Boundary Layer
PCA	Polar Cap Absorption
PFRR	Poker Flat Research Range
SABER	Sounding of the Atmosphere using Broadband Emission Radiometry
SD	Space Department of the Applied Physics Laboratory
SDP	Software Development Plan
SEC	Space Environment Center
SEE	Solar EUV Experiment
SEON	Solar Electro-optical Observing Network
SFOC	Spaceflight Operations Center
STP	Solar Terrestrial Physics
SWOC	Space Weather Operations Center (Offutt)
SWXS	Space Weather Squadron
Tcl	Tool Command Language
Tk	Toolkit
Tix	Tk Interface Extension
UAF	University of Alaska, Fairbanks
UCAR	University Corporation for Atmospheric Research
UPOS	University Partnering for Operational Support
UTC	Coordinated Universal Time
WDC	World Data Center
WF	Weather Flight
WMO	World Meteorological Organization
XDR	External Data Representation