Appendix E1

CALPUFF Dispersion Modeling of Ocean-Going Vessels Emissions

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CALPUFF Dispersion Modeling of Ocean-Going Vessels Emissions

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1. Background

Air pollution from international trade and goods movement activities in California is a major public health concern at both regional and community levels. The diesel-powered vehicles and engines used to transport goods emit soot, or diesel particulate matter (DPM), and other air pollutants than can increase health risks to nearby residents. Goods movement activities are also a significant source of sulfur oxides (SO_x) and oxides of nitrogen (NO_x) which can contribute to the formation of regional smog and fine particulate matter.

As one of many steps being taken to reduce emissions from goods movement activities, the Air Resources Board (ARB) staff is proposing a fuel quality regulation to reduce emissions from ocean-going vessel (OGV) auxiliary diesel and diesel-electric engines, main propulsion engines, and auxiliary boilers (OGV engines and auxiliary boilers). This proposed regulation is a key element of ARB's Diesel Risk Reduction Plan and Goods Movement Emission Reduction Plan (GMERP) and is essential to reducing exposures to particulate matter (PM) emissions both regionally and in communities near maritime ports. (ARB 2000, ARB 2006). Two recent health risk assessments by ARB staff have shown that DPM emissions from OGVs are one of the largest contributors of toxic pollutants and DPM in neighboring communities. (ARB 2006b, ARB 2008) The proposed regulation would reduce the emissions of DPM, PM, NO_x, SO_x, and "secondarily" formed PM (PM formed in the atmosphere from NO_x and SO_x) by requiring the use of cleaner marine distillate fuels in OGV engines and auxiliary boilers.

ARB staff conducted air dispersion modeling with the CALPUFF modeling system to investigate the on-shore impacts of OGV DPM emissions on ambient concentration levels and potential on the associated cancer risks statewide. This document describes the modeling system and model-simulated results for estimating on-shore DPM impacts.

2. Modeling System

The CALPUFF modeling system was selected to carry out the modeling as a means of demonstrating the impact of off-shore OGV emissions. CALPUFF has many strengths, including computational efficiency, flexible emission data processing (i.e., easier to reformat emission data and to represent emission characteristics, compared to the preparation of gridded emission files for grid-based models), the ability to represent the micro-scale dispersion of directly emitted diesel PM, and the ability to place discrete receptors in the modeling domain.

At the time that ARB staff started this modeling exercise, the then official USEPA-approved version was used. The modeling system was publicly available on USEPA's website:

http://www.epa.gov/scram001/dispersion_prefrec.htm#calpuff

The USEPA recommended the following version/level of the meteorological pre-processor (CALMET), dispersion model (CALPUFF) and post-processor (CALPOST):

- CALPUFF - Version 5.711a - July 16, 2004
- CALMET - Version 5.53a - July 16, 2004
- CALPOST - Version 5.51 - July 9, 2003

2.1 CALMET

CALMET is a diagnostic meteorological model. It has been under constant update and improvement by the developer (Scire, 2000).

CALMET uses a two-step approach to calculate wind fields. In the first step, an initial-guess wind field is adjusted for slope flows and terrain blocking effects using terrain data to produce a secondary wind field. The initial guess wind fields used for this project are based on 12-km resolution MM5 meteorological fields for 2002 . In the second step, an objective analysis, based on the adjusted MM5 (initial guess) meteorology, is performed on observational data to produce a final uniform, 3-dimensional, observation-based wind field at all grid points.

The modeling domain is shown in Figure 1. It is based on a Lambert Conformal Conic projection. This modeling domain has been used by ARB staff in statewide modeling exercises. The domain is 1092 km x 1092 km in the longitudinal and meridional directions, respectively, with 4-kilometer grid resolution.

Gridded terrain elevations for the modeling domain are derived from 3 arc-second digital elevation models (DEMs) produced by the United States Geological Survey (USGS). The files cover 1-degree by 1-degree blocks of latitude and longitude. USGS 1:250,000 scale DEMs were used. These DEM data have a resolution of about 90 meters. Terrain elevations are shown in Figure 1.

The land use data are based on the Composite Theme Grid format (CTG) using Level I USGS land use categories. The USGS land use categories were mapped into 14 CALMET land use categories. Land use categories in the modeling domain are shown in Figure 2. The land use categories are described in Table 1.

Key CALMET parameters are summarized in Table 2.

Terrain elevations in the statewide regional modeling domain

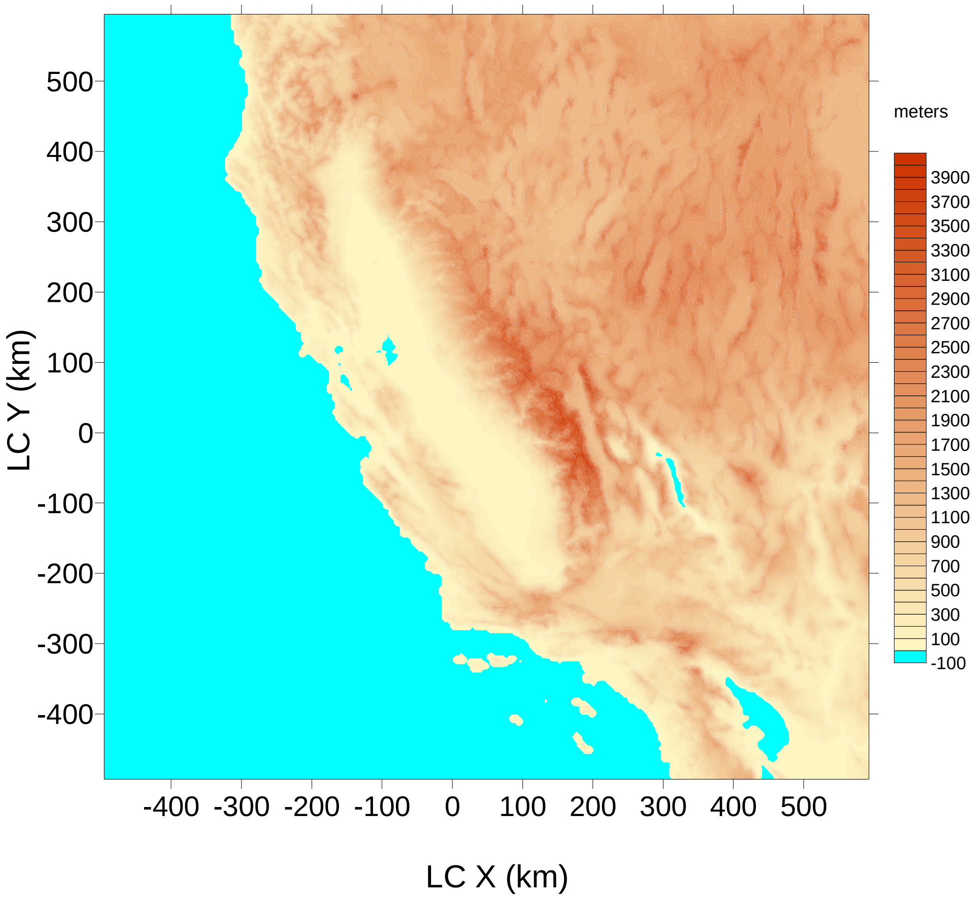

Figure 1. CALMET/CALPUFF modeling domain.

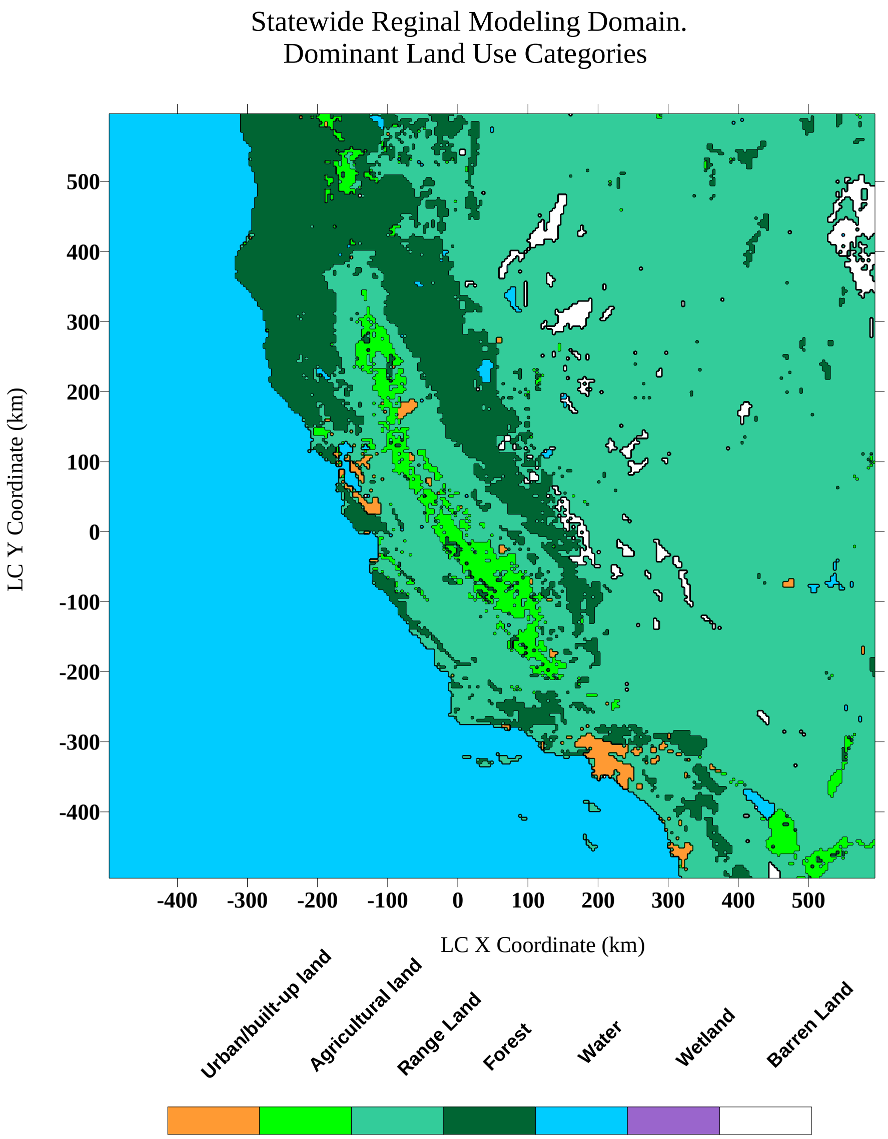

Figure 2. CALMET land use categories.

Table 1. Land use categories table from CALMET User's Guide.

Default CALMET Land Use Categories and Associated Geophysical Parameters
Based on the U.S. Geological Survey Land Use Classification System
(14-Category System)

Land Use Type	Description	Surface Roughness (m)	Albedo	Bowen Ratio	Soil Heat Flux Parameter	Anthropogenic Heat Flux (W/m^2)	Leaf Area Index
10	Urban or Built-up Land	1.0	0.18	1.5	.25	0.0	0.2
20	Agricultural Land - Unirrigated	0.25	0.15	1.0	.15	0.0	3.0
-20*	Agricultural Land - Irrigated	0.25	0.15	0.5	.15	0.0	3.0
30	Rangeland	0.05	0.25	1.0	.15	0.0	0.5
40	Forest Land	1.0	0.10	1.0	.15	0.0	7.0
51	Small Water Body	0.001	0.10	0.0	1.0	0.0	0.0
54	Bays and Estuaries	0.001	0.10	0.0	1.0	0.0	0.0
55	Large Water Body	0.001	0.10	0.0	1.0	0.0	0.0
60	Wetland	1.0	0.10	0.5	.25	0.0	2.0
61	Forested Wetland	1.0	0.1	0.5	0.25	0.0	2.0
62	Nonforested Wetland	0.2	0.1	0.1	0.25	0.0	1.0
70	Barren Land	0.05	0.30	1.0	.15	0.0	0.05
80	Tundra	.20	0.30	0.5	.15	0.0	0.0
90	Perennial Snow or Ice	.20	0.70	0.5	.15	0.0	0.0

* Negative values indicate "irrigated" land use

Table 2. CALMET parameter summary (N/A = not applicable).

Variable	Description	EPA Default	Our Values
GEO.DAT	Name of Geophysical data file	GEO.DAT	GEO.DAT
SURF.DAT	Name of Surface data file	SURF.DAT	SURF.DAT
PRECIP.DAT	Name of Precipitation data file	PRECIP.DAT	NA
NUSTA	Number of upper air data sites	User Defined	0
UPn.DAT	Names of NUSTA upper air data files	UPn.DAT	NA
IBYR	Beginning year	User Defines	2002
IBMO	Beginning month	User Defines	1
IBDY	Beginning day	User Defines	1
IBHR	Beginning hour	User Defines	0
IBTZ	Base time zone	User Defines	8
IRLG	Number of hours to simulate	User Defines	8760
IRTYPE	Output file type to create (must be 1 for CALPUFF)	1	1
LCALGRD	Are w-components and temperature needed?	T	T
NX	Number of east-west grid cells	User Defines	273
NY	Number of north-south grid cells	User Defines	273
DGRIDKM	Grid spacing	User Defines	4
XORIGKM	Southwest grid cell X coordinate	User Defines	-497.132
YORIGKM	Southwest grid cell Y coordinate	User Defines	-494.910
XLATO	Southwest grid cell latitude	User Defines	32.310

Table 2 (continued)

Variable	Description	EPA Default	Our Values
YLONO	Southwest grid cell longitude	User Defines	125.831
IUTMZN	UTM Zone	User Defines	NA
XLAT1	Latitude of 1st standard parallel	User Defines	30
XLAT2	Latitude of 2nd standard parallel	User Defines	60
RLON0	Longitude used if LLCONF = T	User Defines	120.5
RLAT0	Latitude used if LLCONF = T	User Defines	37
NZ	Number of vertical Layers	User Defines	12
ZFACE	Vertical cell face heights (NZ+1 values)	User Defines	0,20,40,80,160,300,600,1000, 1500,2200,3000,4000, and 5000
LSAVE	Save met. Data fields in an unformatted file?	T	T
IFORMO	Format of unformatted file (1 for CALPUFF)	1	1
NSSTA	Number of stations in SURF.DAT file	User Defines	164
NPSTA	Number of stations in PRECIP.DAT	User Defines	0
ICLOUD	Is cloud data to be input as gridded fields? 0=No)	0	0
IFORMS	Format of surface data (2 = formatted)	2	2
IFORMP	Format of precipitation data (2= formatted)	2	2
IFORMC	Format of cloud data (2= formatted)	2	2
IWFCOD	Generate winds by diagnostic wind module? (1 = Yes)	1	1
IFRADJ	Adjust winds using Froude number effects? (1= Yes)	1	1
IKINE	Adjust winds using Kinematic effects? (1 = Yes)	0	0
IOBR	Use O'Brien procedure for vertical winds? (0 = No)	0	0
ISLOPE	Compute slope flows? (1 = Yes)	1	1
IEXTRP	Extrapolate surface winds to upper layers? (-4 = use similarity theory and ignore layer 1 of upper air station data)	-4	-4
ICALM	Extrapolate surface calms to upper layers? (0 = No)	0	0
BIAS	Surface/upper-air weighting factors (NZ values)	NZ*0	NZ*0
IPROG	Using prognostic or MM-FDDA data? (0 = No)		14
LVARY	Use varying radius to develop surface winds?	F	F
RMAX1	Max surface over-land extrapolation radius (km)	User Defines	30
RMAX2	Max aloft over-land extrapolations radius (km)	User Defines	30

Table 2 (continued)

Variable	Description	EPA Default	Our Values
RMAX3	Maximum over-water extrapolation radius (km)	User Defines	50
RMIN	Minimum extrapolation radius (km)	0.1	0.1
RMIN2	Distance (km) around an upper air site where vertical extrapolation is excluded (Set to –1 if IEXTRP = ±4)	4	4
TERRAD	Radius of influence of terrain features (km)	User Defines	50
R1	Relative weight at surface of Step 1 field and obs	User Defines	1.0
R2	Relative weight aloft of Step 1 field and obs	User Defines	1.0
DIVLIM	Maximum acceptable divergence	5.E-6	5.E-6
NITER	Max number of passes in divergence minimization	50	50
NSMTH	Number of passes in smoothing (NZ values)	2,4*(NZ-1)	2,4*(NZ-1)
NINTR2	Max number of stations for interpolations (NA values)	99	99
CRITFN	Critical Froude number	1	1
ALPHA	Empirical factor triggering kinematic effects	0.1	0.1
IDIOPT1	Compute temperatures from observations (0 = True)	0	0
ISURFT	Surface station to use for surface temperature (between 1 and NSSTA)	User Defines	1
IDIOPT2	Compute domain-average lapse rates? (0 = True)	0	0
IUPT	Station for lapse rates (between 1 and NUSTA)	User Defines	NA
ZUPT	Depth of domain-average lapse rate (m)	200	200
IDIOPT3	Compute internally initial guess winds? (0 = True)	0	0
IUPWND	Upper air station for domain winds (-1 = 1/r**2 interpolation of all stations)	-1	-1
ZUPWND	Bottom and top of layer for 1st guess winds (m)	1,1000	1,1000
IDIOPT4	Read surface winds from SURF.DAT? (0 = True)	0	0
IDIOPT5	Read aloft winds from UPn.DAT? (0 = True)	0	0
CONSTB	Neutral mixing height B constant	1.41	1.41
CONSTE	Convective mixing height E constant	0.15	0.15
CONSTN	Stable mixing height N constant	2400	2400

Table 2 (continued)

Variable	Description	EPA Default	Our Values
CONSTW	Over-water mixing height W constant	0.16	0.16
FCORIOL	Absolute value of Carioles parameter	1.E-4	1.E-4
IAVEXZI	Spatial averaging of mixing heights? (1 = True)	1	1
MNMDAV	Max averaging radius (number of grid cells)	1	1
HAFANG	Half-angle for looking upwind (degrees)	30	30
ILEVZI	Layer to use in upwind averaging (between 1 and NZ)	1	1
DPTMIN	Minimum capping potential temperature lapse rate	0.001	0.001
DZZI	Depth for computing capping lapse rate (m)	200	200
ZIMIN	Minimum over-land mixing height (m)	50	50
ZIMAX	Maximum over-land mixing height (m)	3000	3000
ZIMINW	Minimum over-water mixing height (m)	50	50
ZIMAXW	Maximum over-water mixing height (m)	3000	3000
IRAD	Form of temperature interpolation (1 = 1/r)	1	1
TRADKM	Radius of temperature interpolation (km)	500	500
NUMTS	Max number of stations in temperature interpolations	5	5
IAVET	Conduct spatial averaging of temperature? (1 = True)	1	0
TGDEFB	Default over-water mixed layer lapse rate (K/m)	-0.0098	-0.0098
TGDEFA	Default over-water capping lapse rate (K/m)	-0.0045	-0.0045
JWAT1	Beginning landuse type defining water	999	999
JWAT2	Ending landuse type defining water	999	999
NFLAGP	Method for precipitation interpolation (2= 1/r**2)	2	2
SIGMAP	Precip radius for interpolations (km)	100	100
CUTP	Minimum cut off precip rate (mm/hr)	0.01	0.01
SSn	NSSTA input records for surface stations	User Defines	NA
Usn	NUSTA input records for upper-air stations	User Defines	NA
PSn	NPSTA input records for precipitations stations	User Defines	NA

2.2 CALPUFF

CALPUFF is a multi-layer, multi-species non-steady-state Gaussian puff dispersion model which can simulate the effects of time- and space-varying meteorological conditions on pollutant transport, transformation, and removal. CALPUFF contains algorithms for near-source effects such as building downwash, transitional plume rise, subgrid scale terrain interactions as well as longer range effects such as pollutant removal (wet scavenging and dry deposition), chemical transformation, vertical wind shear, overwater transport and coastal interaction effects.

The CALPUFF modeling domain is identical to the CALMET modeling domain.

Key CALPUFF settings are summarized in Table 3.

Table 3. CALPUFF parameter summary.

Variable	Description	EPA Default	Our Values
METDAT	CALMET input data filename	CALMET.DAT	CALMET.DAT
PUFLST	Filename for general output from CALPUFF	CALPUFF.LST	CALPUFF.LST
CONDAT	Filename for output concentration data	CONC.DAT	CONC.DAT
DFDAT	Filename for output dry deposition fluxes	DFLX.DAT	DFLX.DAT
WFDAT	Filename for output wet deposition fluxes	WFLX.DAT	WFLX.DAT
VISDAT	Filename for output relative humidities (for visibility)	VISB.DAT	VISB.DAT
METRUN	Do we run all periods (1) or a subset (0)?	0	0
IBYR	Beginning year	User Defined	2002
IBMO	Beginning month	User Defined	1
IBDY	Beginning day	User Defined	1
IBHR	Beginning hour	User Defined	0
IRLG	Length of runs (hours)	User Defined	8760
NSPEC	Number of species modeled (for MESOPUFF II chemistry)	User Defined	6
NSE	Number of species emitted	3	3
MRESTART	Restart options (0 = no restart), allows splitting runs into smaller segments	0	1
METFM	Format of input meteorology (1 = CALMET)	1	1
AVET	Averaging time lateral dispersion parameters (minutes)	60	60
MGAUSS	Near-field vertical distribution (1 = Gaussian)	1	1
MCTADJ	Terrain adjustments to plume path (3 = Plume path)	3	3
MCTSG	Do we have subgrid hills? (0 = No), allows CTDM-like treatment for subgrid scale hills	0	0

Table 3 (continued)

Variable	Description	EPA Default	Our Values
MSLUG	Near-field puff treatment (0 = No slugs)	0	0
MTRANS	Model transitional plume rise? (1 = Yes)	1	1
MTIP	Treat stack tip downwash? (1 = Yes)	1	1
MSHEAR	Treat vertical wind shear? (0 = No)	0	0
MSPLIT	Allow puffs to split? (0 = No)	0	0
MCHEM	MESOPUFF-II Chemistry? (1 = Yes)	1	1
MWET	Model wet deposition? (1 = Yes)	1	1
MDRY	Model dry deposition? (1 = Yes)	1	1
MDISP	Method for dispersion coefficients (3 = PG & MP)	3	3
MTURBVW	Turbulence characterization? (Only if MDISP = 1 or 5)	3	3
MDISP2	Backup coefficients (Only if MDISP = 1 or 5)	3	3
MROUGH	Adjust PG for surface roughness? (0 = No)	0	0
MPARTL	Model partial plume penetration? (0 = No)	1	1
MTINV	Elevated inversion strength (0 = compute from data)	0	0
MPDF	Use PDF for convective dispersion? (0 = No)	0	0
MSGTIBL	Use TIBL module? (0 = No) allows treatment of subgrid scale coastal areas	0	0
MREG	Regulatory default checks? (1 = Yes)	1	1
CSPECn	Names of species modeled (for MESOPUFF II, must be SO2, SO4, NOx, HNO3, NO3)	User Defined	SO2, SO4, NOx, HNO3, NO3, DPM, CO, NH3, HC
NX	Number of east-west grids of input meteorology	User Defined	273
NY	Number of north-south grids of input meteorology	User Defined	273
NZ	Number of vertical layers of input meteorology	User Defined	12
DGRIDKM	Meteorology grid spacing (km)	User Defined	4
ZFACE	Vertical cell face heights of input meteorology	User Defined	12
XORIGKM	Southwest corner (east-west) of input meteorology	User Defined	-497.132
YORIGIM	Southwest corner (north-south) of input meteorology	User Defined	-494.910
IUTMZN	UTM zone	User Defined	NA
XLAT	Latitude of center of meteorology domain	User Defined	37
XLONG	Longitude of center of meteorology domain	User Defined	120.50
XTZ	Base time zone of input meteorology	User Defined	PST
IBCOMP	Southwest of Xindex of computational domain	User Defined	1
JBCOMP	Southwest of Y-index of computational domain	User Defined	1
IECOMP	Northeast of Xindex of computational domain	User Defined	273

Table 3 (continued)

JECOMP	Northeast of Y- index of computational domain	User Defined	273
LSAMP	Use gridded receptors (T -= Yes)	T	T
IBSAMP	Southwest of Xindex of receptor grid	User Defined	1
JBSAMP	Southwest of Y-index of receptor grid	User Defined	1
IESAMP	Northeast of Xindex of receptor grid	User Defined	273
JESAMP	Northeast of Y-index of receptor grid	User Defined	273
MESHDN	Gridded receptor spacing = DGRIDKM/MESHDN	1	1
ICON	Output concentrations? (1 = Yes)	1	1
IDRY	Output dry deposition flux? (1 = Yes)	1	1
IWET	Output wet deposition flux? (1 = Yes)	1	1
IVIS	Output RH for visibility calculations (1 = Yes)	1	1
LCOMPRS	Use compression option in output? (T = Yes)	T	T
ICPRT	Print concentrations? (0 = No)	0	0
IDPRT	Print dry deposition fluxes (0 = No)	0	0
IWPRT	Print wet deposition fluxes (0 = No)	0	0
ICFRQ	Concentration print interval (1 = hourly)	1	1
IDFRQ	Dry deposition flux print interval (1 = hourly)	1	1
IWFRQ	Wet deposition flux print interval (1 = hourly)	1	1
IPRTU	Print output units (1 = g/m**3; g/m**2/s)	1	1
IMESG	Status messages to screen? (1 = Yes)	1	1
Output Species	Where to output various species	User Defined	All modeled species
LDEBUG	Turn on debug tracking? (F = No)	F	F
Dry Gas Dep	Chemical parameters of gaseous deposition species	User Defined	SO2,NOx
Dry Part. Dep	Chemical parameters of particulate deposition species	User Defined	DPM
RCUTR	Reference cuticle resistance (s/cm)	30.	30.
RGR	Reference ground resistance (s/cm)	10.	10.
REACTR	Reference reactivity	8	8
NINT	Number of particle-size intervals	9	9
IVEG	Vegetative state (1 = active and unstressed)	1	1
Wet Dep	Wet deposition parameters	User Defined	DPM
MOZ	Ozone background? (1 = read from ozone.dat)	1	0
BCKO3	Ozone default (ppb) (Use only for missing data)	80	80
BCKNH3	Ammonia background (ppb)	10	10
RNITE1	Nighttime SO2 loss rate (%/hr)	0.2	0.2
RNITE2	Nighttime Nox loss rate (%/hr)	2	2
RNITE3	Nighttime HNO3 loss rate (%/hr)	2	2
SYTDEP	Horizontal size (m) to switch to time dependence	550.	550.
MHFTSE	Use Heffter for vertical dispersion? (0 = No)	1	1

Table 3 (continued)

JSUP	PG Stability class above mixed layer	5	5
CONK1	Stable dispersion constant (Eq. 2.7-3)	0.01	0.01
CONK2	Neutral dispersion constant (Eq. 2.7-4)	0.1	0.1
TBD	Transition for downwash algorithms (0.5 = ISC)	0.5	0.5
IURB1	Beginning urban landuse type	10	10
IURB2	Ending urban landuse type	19	19

3. OGV Emission Data

ARB staff developed a 2005 statewide emission inventory (2005 MM2.0) for OGVs operating in California coastal waters and California ports and inland waterways to use in CALPUFF modeling.

Figure 3 shows the spatial distribution of OGV DPM emissions. Three sub-categories are included in the total emissions: transiting, maneuvering, and hotelling. The domain wide DPM emission total is 26.9 t/d. This includes emissions within the 24 nm regulatory zone and the 100 nm emission inventory zone used in the statewide emissions inventory as well as emissions within the domain boundary that are beyond the 100 nm emission inventory zone. Among this emission total, 2.8 t/d is from hotelling emissions, 0.5 t/d is from maneuvering emissions, and the remainder is from transiting emissions. More than 60% of the total emissions are confined to the region that extends from the coastline to 24 nm off shore (referred to from here on as “the 24 nm zone”): 16.7 t/d of DPM is emitted within the 24 nm zone (including hotelling, maneuvering and transiting emissions).

For modeling purposes, all OGV sources were characterized as area sources within 4 km x 4 km grid cells that coincide with CALMET/CALPUFF grid cells. Initial plume height and initial σ_z (which characterizes initial plume spread) were assumed to be 50 m and 25 m, respectively. Because emissions within each grid cell are treated as an area source, i.e., emissions are assumed to be uniformly distributed within the grid cell, the characterization of how the pollutants are emitted is simplified in the model and expressed by initial plume height and initial plume spread. Plume rise, wind speed, vessel engine load, and vessel speed are among the factors that affect these two parameters. In the model initial plume height and initial plume spread represent, on average, how plumes are diffused within the cell. It is difficult to make a determination what values should be used, but sensitivity studies (different combinations of initial plume height and spread: 10 m and 100 m, 40 m and 10m, 20 m and 20 m) suggest that the on-shore ground level concentrations are not sensitive to initial plume height and initial plume spread.

Ocean-Going Vessels Emissions

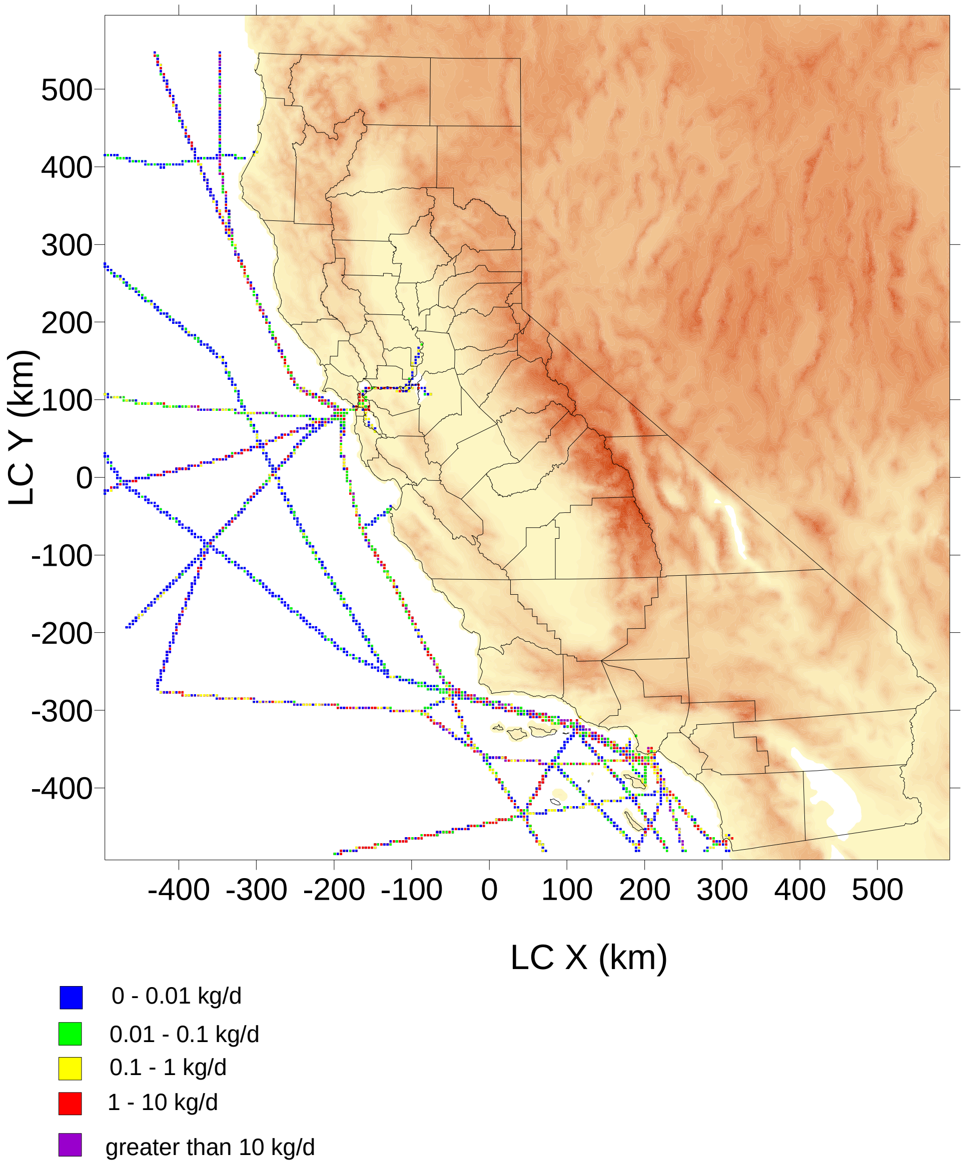

Figure 3. OGV DPM emission distribution.

4. Modeling Results

CALPUFF was run with the previously described inputs and model setup, including a 2005 OGV emission inventory and 2002 meteorological data. Hourly concentrations of DPM were generated. The results presented illustrate estimated on-shore impact strictly from OGV emissions.

Both dry and wet deposition is considered in the modeling. Dry deposition is determined by deposition velocity which is calculated with a resistance deposition model. Wet deposition is determined by a number of factors including precipitation rate and a scavenging coefficient.

Figure 4 presents model-estimated spatial concentration isopleths for annual average DPM concentrations. The unit of concentration is $\mu g/m^3$. The excess cancer risk due to the DPM concentrations that are illustrated in Figure 4 is shown in Figure 5. The risk was calculated using the annual average DPM concentrations predicted by CALPUFF, and an estimated cancer risk of 318 excess cancer cases per million people breathing air with 1 $\mu g/m^3$ DPM over a lifetime. The excess cancer risk factor is based on the 80th percentile breathing rate.

The potential cancer risks were estimated using standard risk assessment procedures based on the annual average concentration of DPM predicted by the model and a health risk factor (referred to as a cancer potency factor) that correlates cancer risk to the amount of DPM inhaled.

The methodology used to estimate the potential cancer risks is consistent with the Tier-1 analysis presented in OEHHA's Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments (OEHHA, 2003). A Tier-1 analysis assumes that an individual is exposed to an annual average concentration of a pollutant continuously for 70 years.[1] The cancer potency factor was developed by the OEHHA and approved by the State's Scientific Review Panel on Toxic Air Contaminants (SRP) as part of the process of identifying diesel PM emission as a toxic air contaminant (TAC).

The estimated DPM concentrations and cancer risk levels produced by a risk assessment are based on a number of assumptions. Many of the assumptions are designed to be health protective so that potential risks to individuals are not underestimated. Therefore, the actual cancer risk calculated is intentionally designed to avoid under-prediction. There are also many uncertainties in the health values used in the risk assessment.

[1]According to the OEHHA Guidelines, the relatively health-protective assumptions incorporated into the Tier-1 risk assessment make it unlikely that the risks are underestimated for the general population.

Figure 6, 7 and 8 show excess cancer risk attributed to emissions from transiting, maneuvering and hotelling.

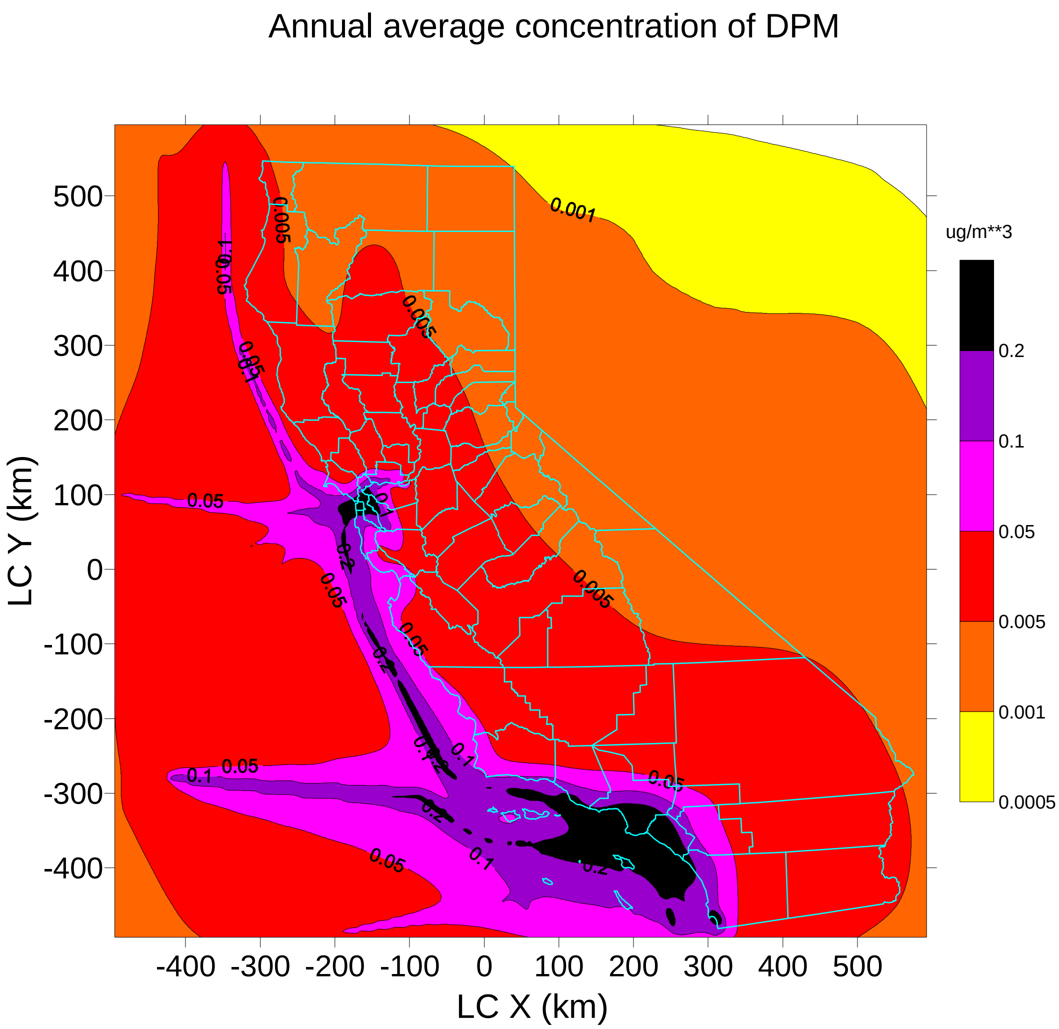

Figure 4. Annual average of DPM concentration.

Excess cancer risk: all OGV emissions
(Transiting, Maneuvering, and Hotelling)

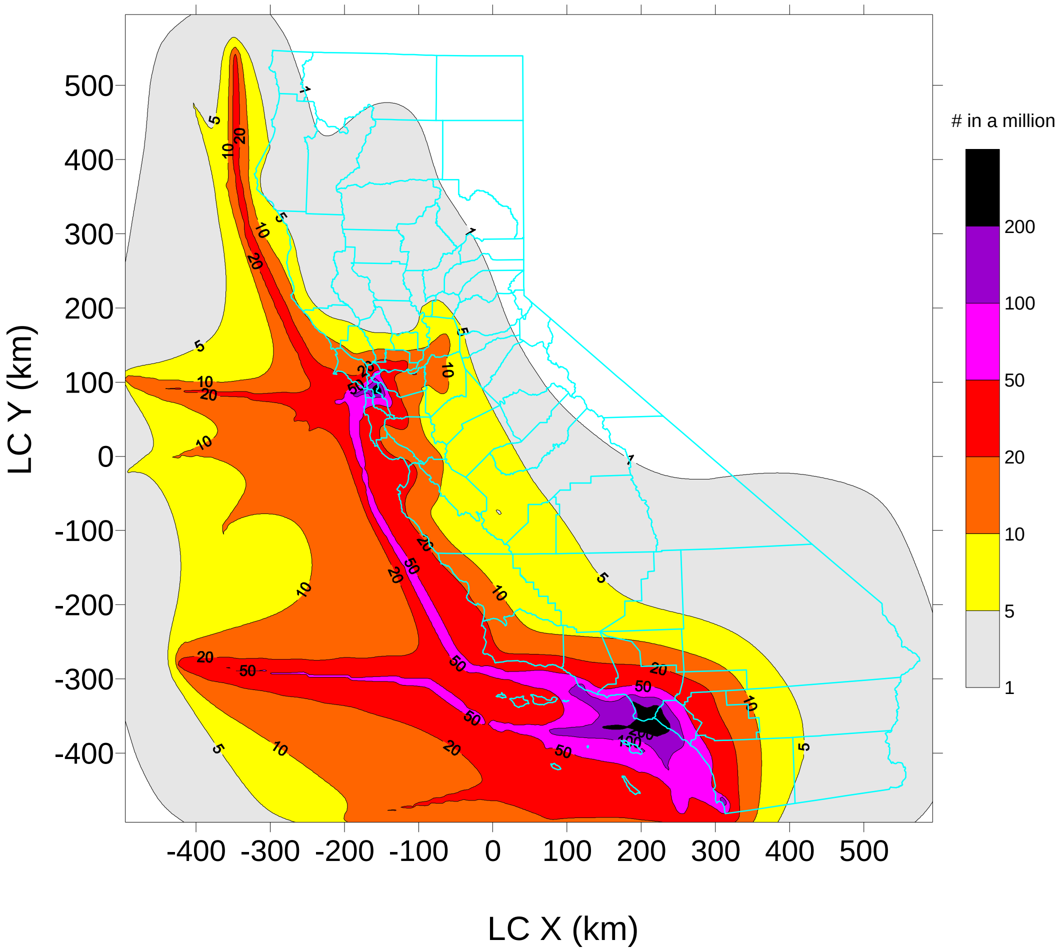

Figure 5. Excess cancer risk from OGV emissions of DPM.

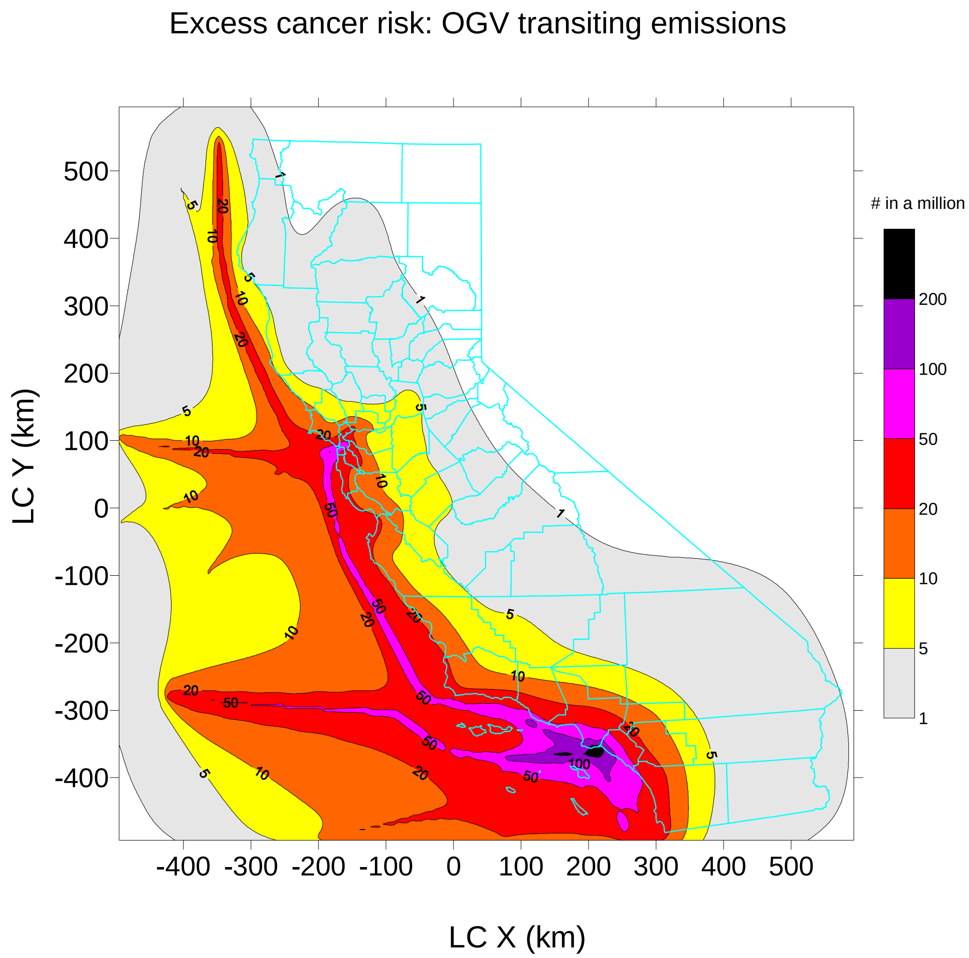

Figure 6. Excess cancer risk from OGV transiting emissions of DPM.

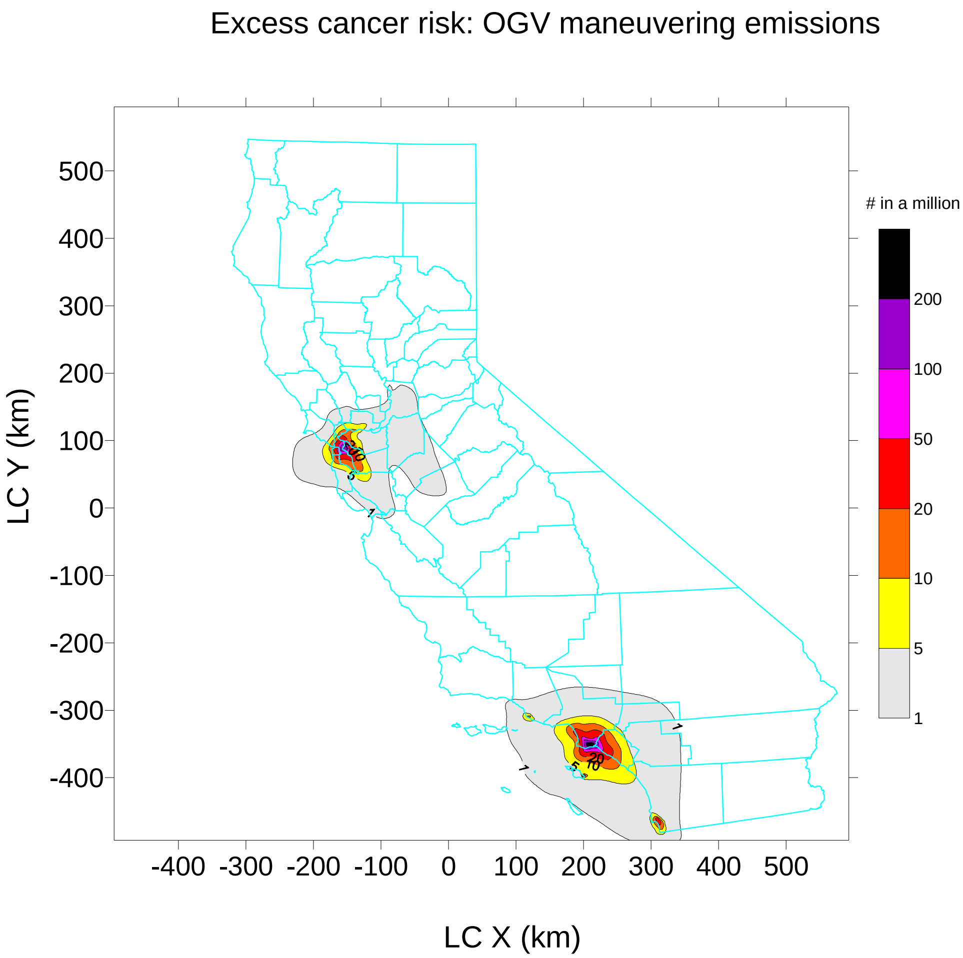

Figure 7. Excess cancer risk from OGV maneuvering emissions of DPM.

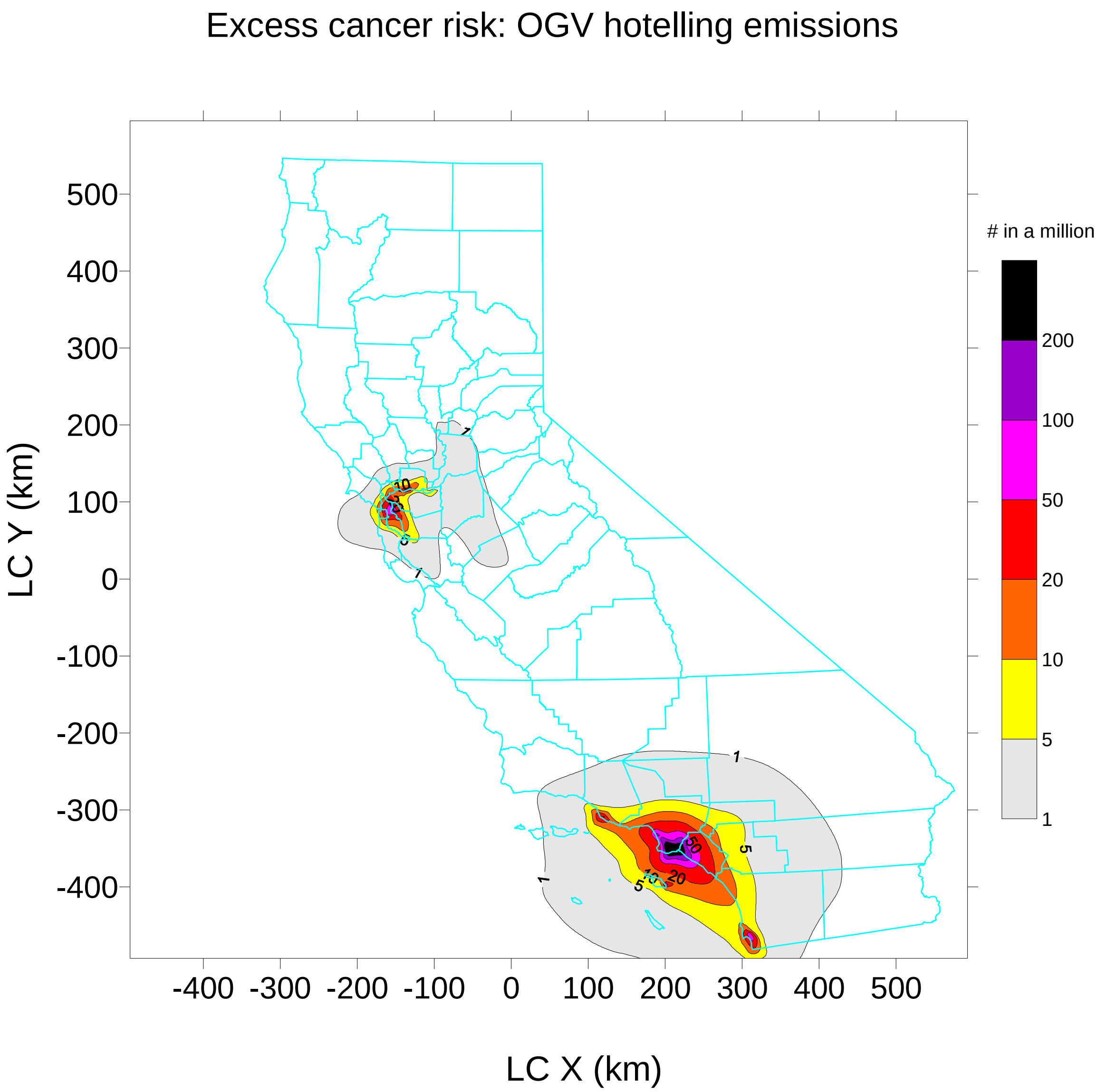

Figure 8. Excess cancer risk from OGV hotelling emissions of DPM.

5. Model Performance

It is difficult to do a rigorous model performance evaluation due to the lack of air quality monitoring data over the ocean. Furthermore, because DPM can not be directly measured, it is not even possible to directly evaluate the model's performance of calculating DPM concentrations based on observations.

DPM concentrations were estimated in previous studies in coastal areas in southern California (CARB, 2006; SCAQMD, 2008). The present DPM concentrations compare quite well with the CARB 2006 results for OGV emissions. The MATES III study (SCAQMD, 2008) included all emission source categories and the spatial distribution of emissions for each emission categories are quite different (e.g., the distributions of OGV and of diesel trucks). The present modeling results (for OGV emissions only) are quite similar to MATES III results for ship emissions, and the location of highest DPM concentrations is near ports of Los Angeles and Long Beach where the highest OGV emissions occur.

Sensitivity tests were conducted to examine the effect of source height and of initial mixing. Three sets of parameters were used: (1) source height at 10 m with 100 m initial mixing; (2) 20 m source height and 20 m initial mixing; and (3) 40 m source height and 10 m initial mixing. Because of the computational burden, the tests were carried out with a subset of emission sources and with January 2002 meteorology. The concentration isopleths looked very similar and the on-shore concentrations were almost identical.

6. Reference

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