HYSPLIT

Hybrid Single Particle Lagrangian
Integrated Trajectory Model

Radionuclide Applications

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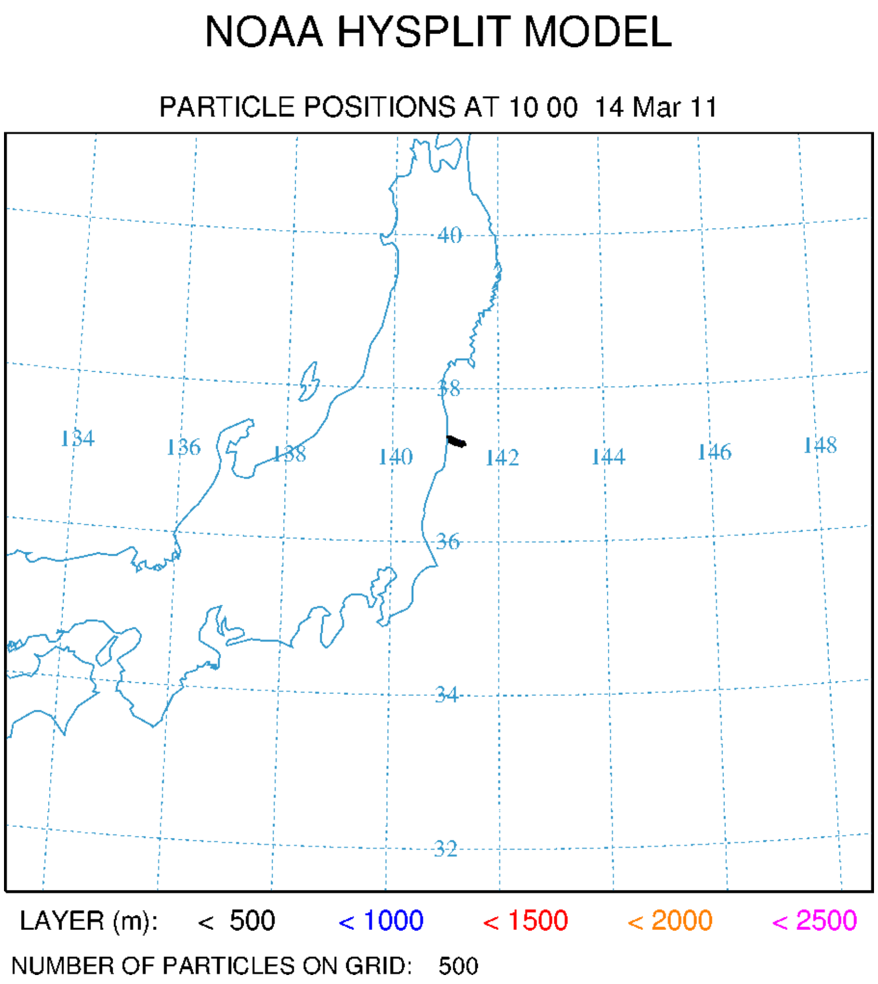
HYSPLIT Overview

- HYSPLIT is not just a transport and dispersion model but a complete system for computing trajectories, dispersion, and deposition
- Can be applied to different air quality problems
- Specific applications depend upon configuration of input files and the use of pre- and post-processing executables
- Executable library contains over 100 applications
- This presentation is a highly technical focus on configuring the model for radiological applications
- This presentation was developed as a reference document

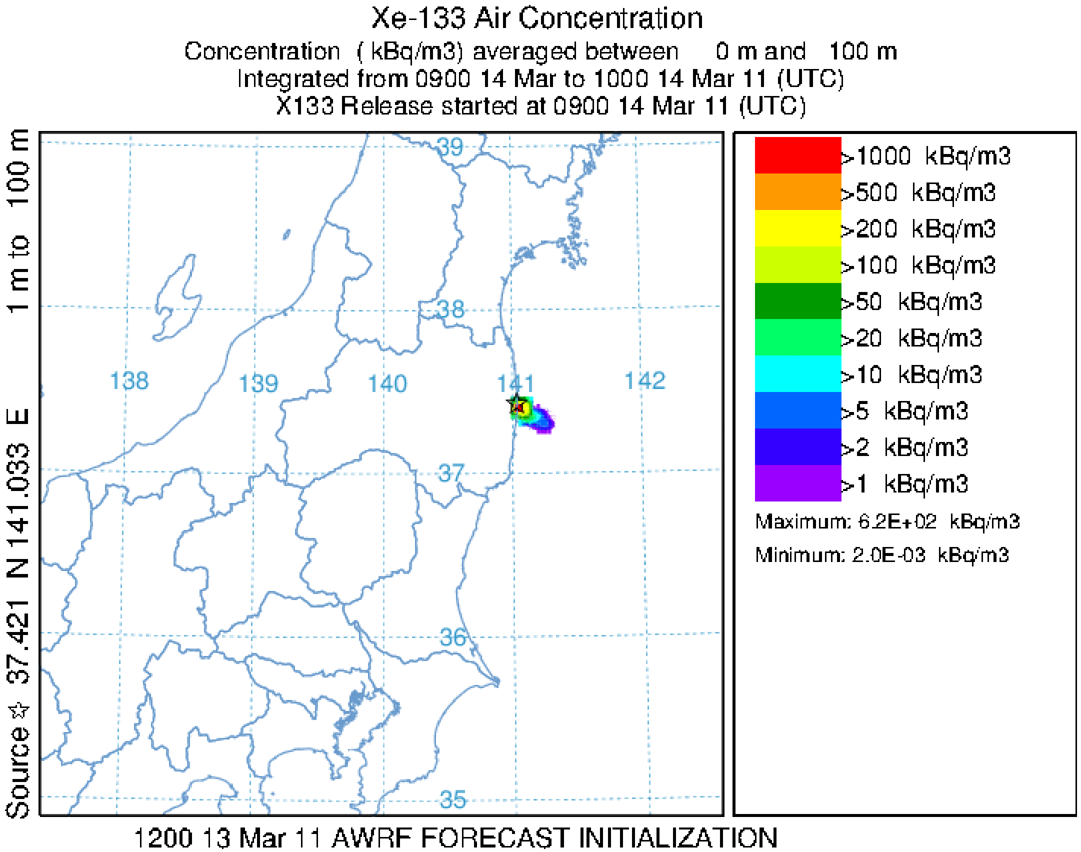
HYSPLIT

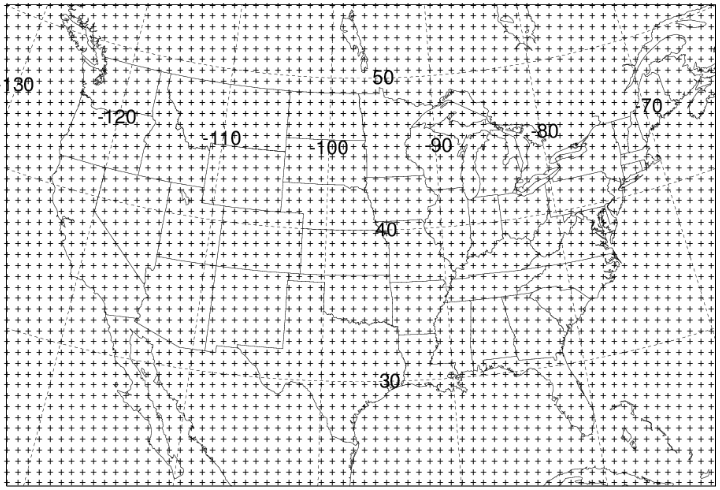
- Computational particle is a surrogate for a radionuclide gas or particle
- A single computational particle may represent one or more radionuclides
- A particle follows the mean motion of the spatially and temporally varying wind field
- Random velocities are added to the mean motion to represent turbulence
- All subsequent examples will focus on the period of 14-16 March 2011 during the Fukushima accident

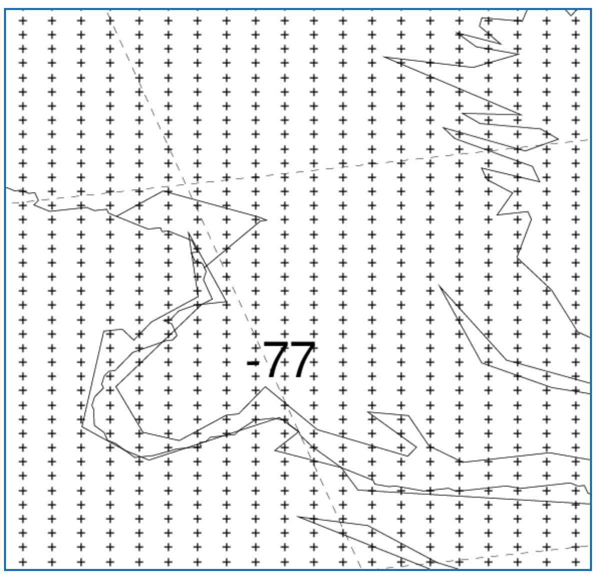


^{133}Xe Example

- Radionuclide mass is assigned to each particle
- Mass is decayed after it is released
- A user defined three-dimensional grid covers the domain
- Particle masses are summed in each grid cell
- The mass sum is divided by the grid cell volume to obtain air concentration



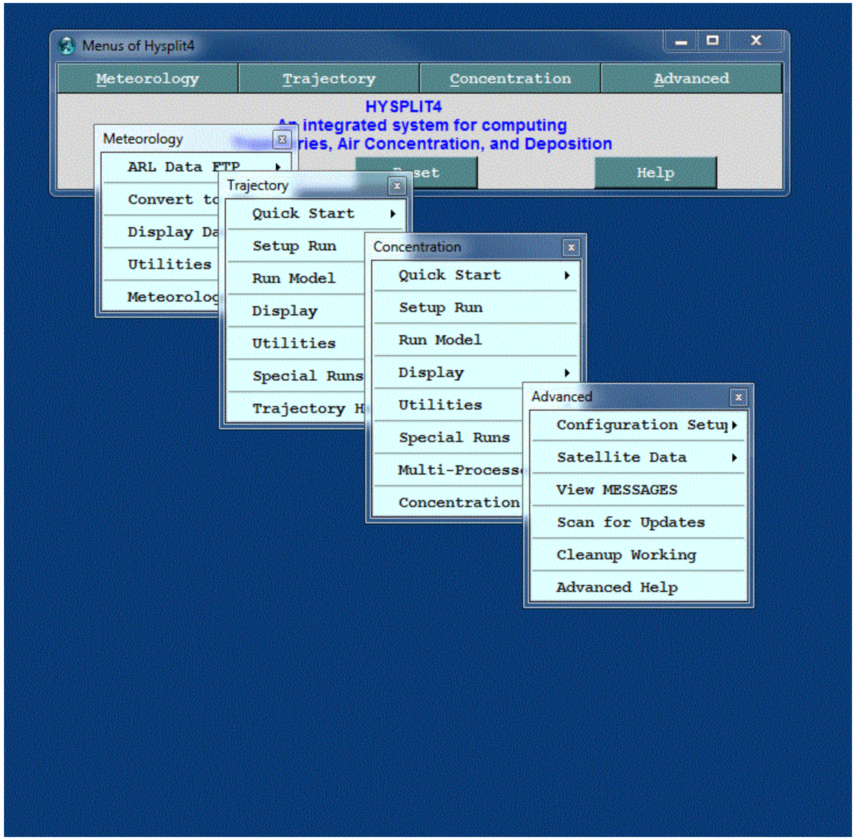




Meteorology

- HYSPLIT requires data in a special direct-access fixed record format
- NCEP operationally produces forecast files and they are available for FTP
- Top left shows the highest resolution routinely available (4 km) at every 20th grid point
- Bottom, zoomed over the Washington DC area showing every grid point
- Forecast and archive data for the CONUS and globally are available:
- ftp://arlftp.arlhq.noaa.gov/pub/
- All the Fukushima examples use results from our own 4-km WRF-ARW simulation

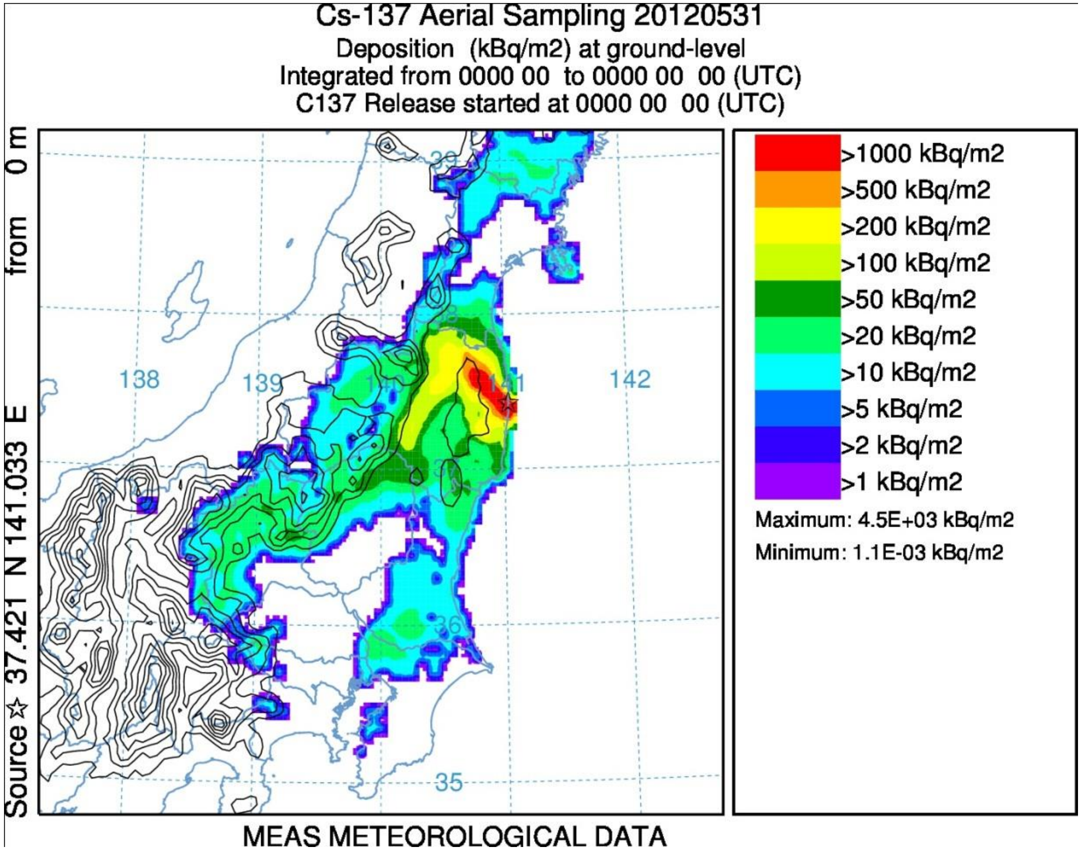
HYSPLIT Availability



- Platforms
  - Windows
  - MAC OS
  - LINUX
  - Web
- Interface
  - Tcl/Tk
  - Command line
- http://ready.arl.noaa.gov/HYSPLIT.php
  - restricted user access for nuclear configuration options

HYSPLIT Assumptions

- Minimum model integration time step = 1 minute
- Then minimum resolution: 5 m/s * 60 s = 300 m
- Standard simulation decay starts at the time of emission
- Different radioactive decay scenarios must be treated in the post-processing step
- In the following Fukushima examples the emission were decay corrected to the reactor shutdown time: 0600 UTC 11 March
- Daughter products are not handled directly



Simple Computational Framework

input | model | output | post-processing

control

namelist

meteorology

HYSPLIT

binary air concentration and deposition

CONCPLOT

CON2STN
C2DATEM

TIMEPLOT

All the following examples have been configured for demonstration purposes and computational speed!

The CONTROL file

11 03 14 09
2
37.4206 141.0329 1.0
37.4206 141.0329 100.0
51
0
10000.0
1
/meteorology/wrf_arl/
W03_201103.bin
1
CPAR
5.887E+13
51.0
00 00 00 00 00
1
38.0 140.0
0.05 0.05
20.0 30.0
./
fdnpp.bin
2
0 100
00 00 00 00 00
00 00 00 00 00
00 03 00
1
1.0 1.0 1.0
0.001 0.0 0.0 0.0 0.0
0.0 8.0E-05 8.0E-05
11025.8
0.0

Average emissions in layer 1-100 m AGL

Average emission rate Cs-137 in Bq/h for a duration of 51 hours

Binary output file

Dry and wet deposition

Decay (days)

The namelist file: SETUP.CFG

```
&SETUP
delt = 5.0,              Time step = 5 minutes
khmax = 24,              Delete particles after 24 h
numpar = -2500,          Release 2500 particles / h
/
```

The minimum concentration for one time-step without deposition:

5.887E+13 Bq/h / 2500 p/h = 2.355E+10 Bq/p

2.355E+10 Bq / 5000 m / 5000 m / 100 m = 9.42 Bq/m3

Now just run HYSPLIT: ..\exec\hycs_std

Post-Processing

C2DATEM	
-ifdnpp.bin	input = HYSPLIT output file
-oTokai.txt	output = text file at Tokai-Mura
-mJAEA_C137.txt	match model to measured data
-c1000.0	convert Bq to mBq
-z2	use level=2 of input file
TIMEPLOT	
-iTokai.txt	model predictions input text file
-sJAEA_C137.txt	measured data file
CONAVGPD -ifdnpp.bin -odeposit.bin	binary output file deposit.bin
-a11031409 -b11031612	between period 14-16 March
-m0.001	convert Bq to kBq
-r1	sum values=1 rather than average=0
CONCPLOT -ideposit.bin	plot binary deposition file
-h37.0:140.0 -g0:500	force map 500 km radius centered
-ukBq	force units label
-c4 -v1000+300+100+30+10	force contours

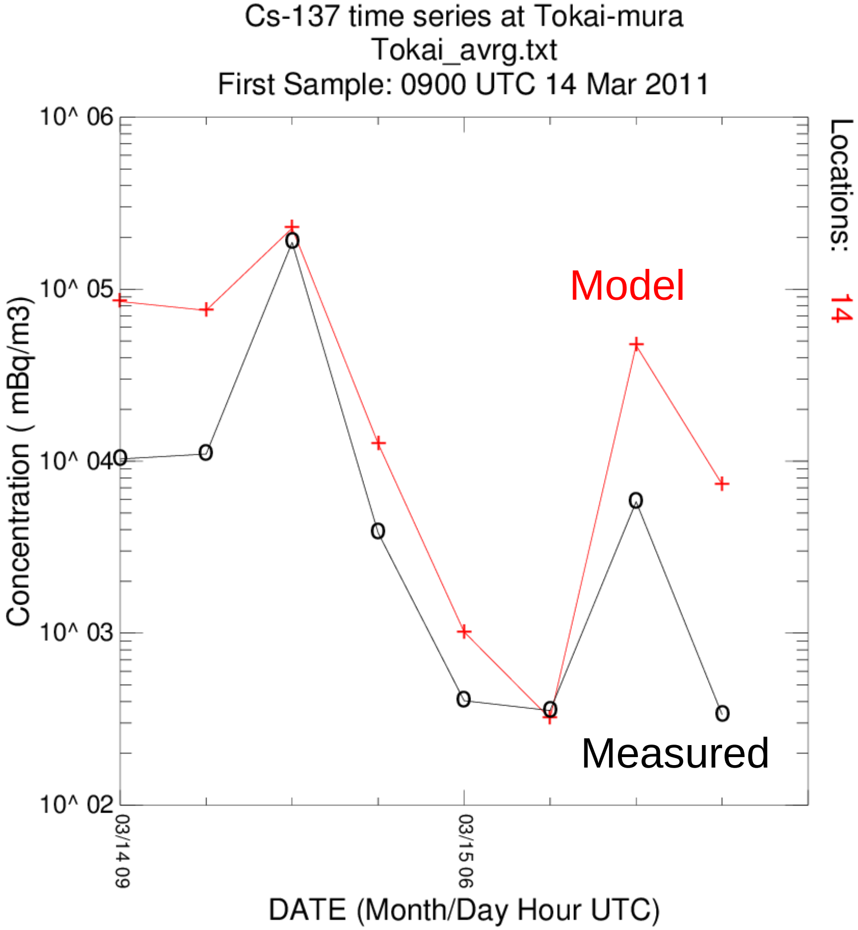
HYSPLIT predictions at Tokai-mura

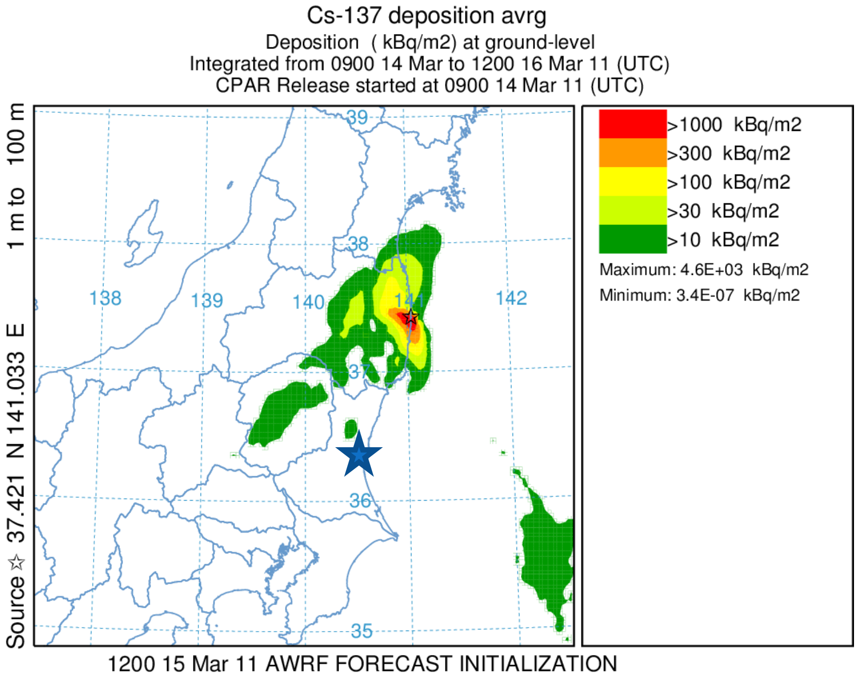
DATEM formatted output from program c2datem

```
fdnpp.bin
year mn dy  shr    dur       Lat       Lon      mBq/m3      id
2011  3 14 0900   0900   36.4356  140.6025   4333.6489      14
2011  3 14 1800   0300   36.4356  140.6025    67054.73      14
2011  3 14 2100   0300   36.4356  140.6025   205302.77      14
2011  3 15 0000   0600   36.4356  140.6025    11450.92      15
2011  3 15 0600   0600   36.4356  140.6025    662.9220      15
2011  3 15 1200   0600   36.4356  140.6025    220.9356      15
2011  3 15 1800   0600   36.4356  140.6025    23165.15      15
2011  3 16 0000   1200   36.4356  140.6025   3305.2449      16
```

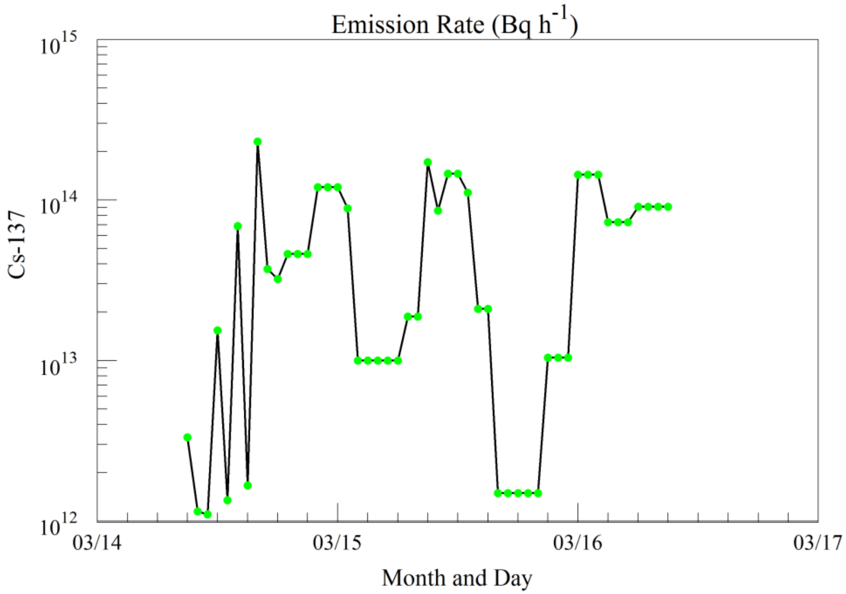
The measured data file JAEA_C137.txt looks just like the file contents shown above except the concentration values are measured rather than model predictions.

Simulation Results using Constant Emission rate





Simulation using Time-Varying Emissions



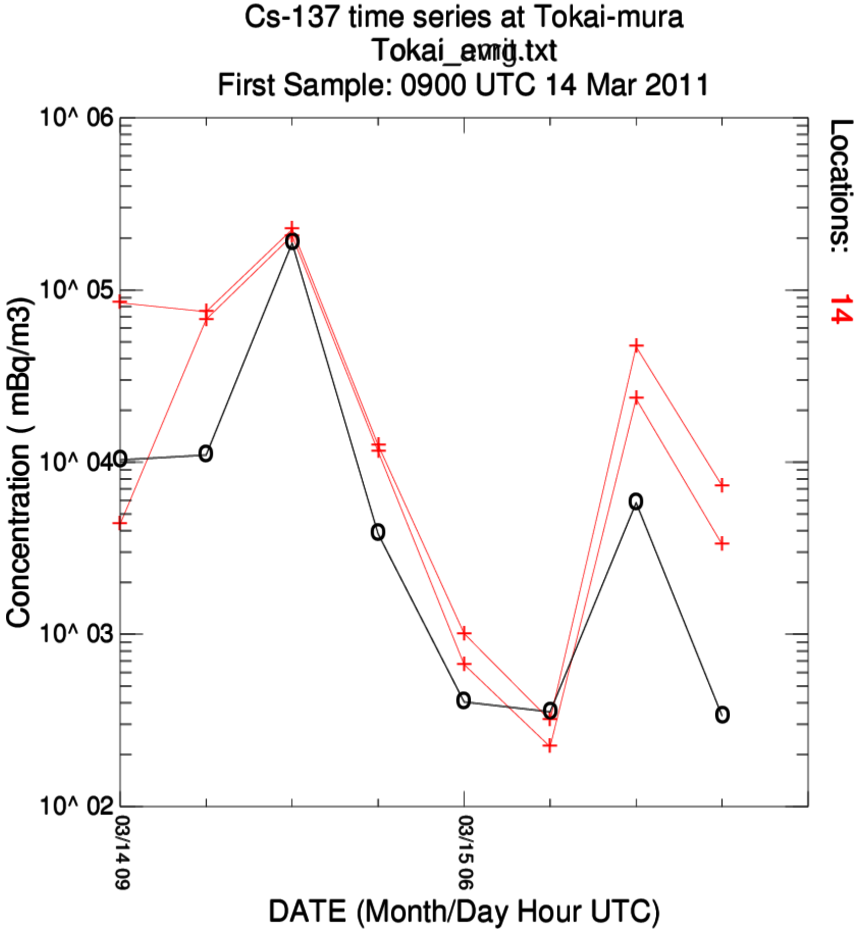
- Define emissions file with namelist variable: efile = 'EMITIMES'
- Turn off emissions in the control file:

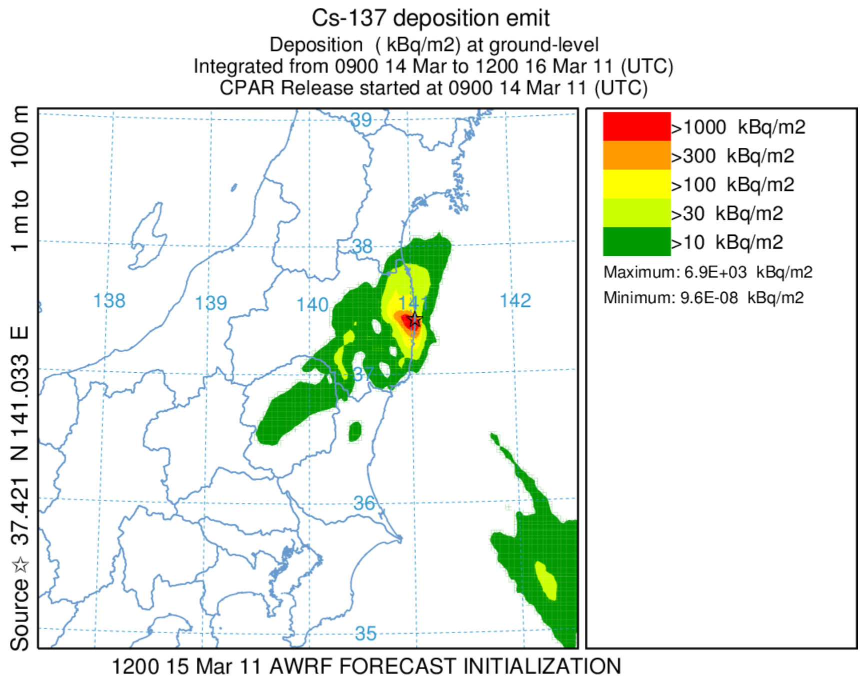
1	1
CPAR	CPAR
5.887E+13	0.0
51.0	0.0

Extract from the EMITIMES file for time-varying emissions

```
YYYY MM DD HH    DURATION(hhhh) #RECORDS
YYYY MM DD HH MM DURATION(hhmm) LAT LON HGT(m) RATE(/h) AREA(m2) HEAT(w)
2011 03 14 09 0003 2
2011 03 14 09 00 0300 37.4206 141.0329   1.0 1.86E+12 0.0 0.0
2011 03 14 09 00 0300 37.4206 141.0329 100.0 1.86E+12 0.0 0.0
2011 03 14 12 0003 2
2011 03 14 12 00 0300 37.4206 141.0329   1.0 2.86E+13 0.0 0.0
2011 03 14 12 00 0300 37.4206 141.0329 100.0 2.86E+13 0.0 0.0
2011 03 14 15 0003 2
2011 03 14 15 00 0300 37.4206 141.0329   1.0 9.00E+13 0.0 0.0
2011 03 14 15 00 0300 37.4206 141.0329 100.0 9.00E+13 0.0 0.0
2011 03 14 18 0003 2
2011 03 14 18 00 0300 37.4206 141.0329   1.0 4.15E+13 0.0 0.0
2011 03 14 18 00 0300 37.4206 141.0329 100.0 4.15E+13 0.0 0.0
2011 03 14 21 0003 2
2011 03 14 21 00 0300 37.4206 141.0329   1.0 9.54E+13 0.0 0.0
2011 03 14 21 00 0300 37.4206 141.0329 100.0 9.54E+13 0.0 0.0
+ 12 more time periods!
```

Simulation Results using a Variable Emission Rate





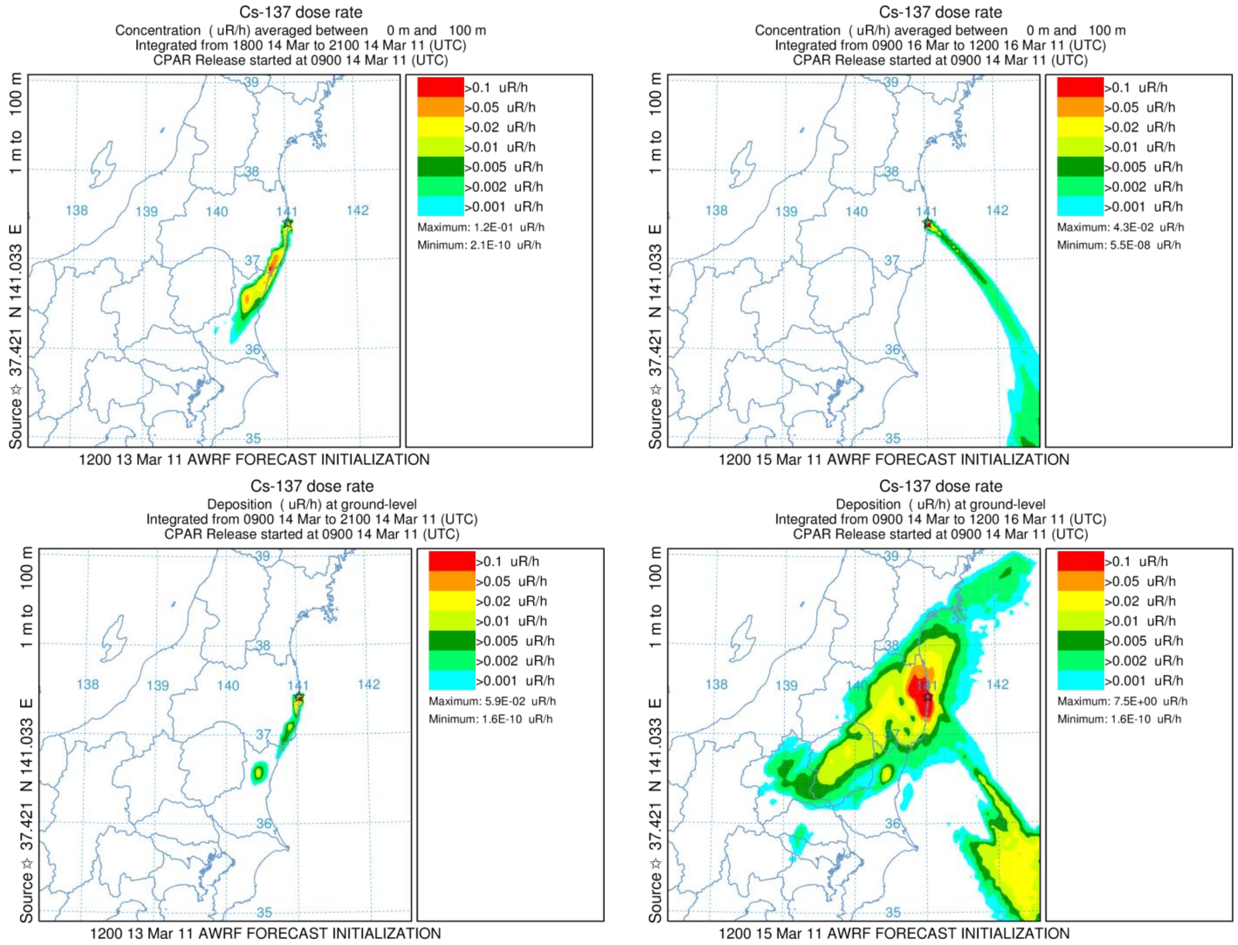
Converting Concentration to Dose

- For Cs-137 (published multiple sources):
  - 3.34080E-11 (rem/h) / (Bq/m^3) for air concentration
  - 1.07640E-12 (rem/h) / (Bq/m^2) for deposition
- CONCPLOT command line add:
  - -x3.34E-05 to convert air concentration to μ-rem/h
  - -y1.08E-06 to convert deposition to μ-rem/h
  - -r2 to time-accumulate deposition
- Cloud shine dose not accumulate like ground shine in this simple approach (using CONCPLOT)

Dose rates at +12 h and +48 h

Cloud-Shine

Ground-Shine



2100Z March 14

1200Z March 16

CON2DOSE: Legacy Dose Conversion

- HYSPLIT simulation for a single species; includes emissions and decay
- Species ID must match entry in con2dose.dat table
- Binary file output with nine different doses:
  - immersion, inhalation, bone, lung, thyroid, acute, long-term, effective, total
- Table conversion units in m-rem/h per $\mu Ci/m^3$

```
 (mrem/hr)
          --------Inhalation (-------) -------    Air       Depos.    Depos.    Depos.
                             (uCi/m**3)         Submersion Ext. Exp.  Ext.    4-day dose
                   Acute     Acute     CDE      Ext. EDE    Rate      EDE      Non-arid/Resusp
Nuclide    CEDE     Bone      Lung    Thyroid   (mrem/hr)/ (mR/hr)/ (mrem/hr)/  (mrem)/
 Name     50-year  30-day    30-day   50-year   (uCi/m**3) (uCi/m**2) (uCi/m**2) (uCi/m**2)
          ALL VALUES FROM FRMAC (1995)
-------   --------  --------  --------  --------  --------  --------  --------  --------
C134     1 5.55E+01  1.02E+01  1.24E+01 -1.00E+00  1.0E+00  2.0E-02  1.4E-02  1.4E+00
C136     1 8.79E+00  6.66E+00  8.88E+00 -1.00E+00  1.4E+00  2.7E-02  1.9E-02  1.7E+00
C137     1 3.83E+01  6.22E+00  9.77E+00 -1.00E+00  3.8E-01  7.6E-03  5.5E-03  5.5E-01
I131     1 3.95E+01  2.40E-01  2.89E+00  1.30E+03  2.4E-01  4.9E-03  3.5E-03  3.0E-01
I132     1 4.57E+00  6.22E-02  1.20E+00  7.73E+00  1.5E+00  2.9E-02  2.1E-02  6.8E-02
I133     1 7.02E+00  1.20E-01  3.64E+00  2.16E+02  3.9E-01  7.8E-03  5.6E-03  1.6E-01
I134     1 1.58E-01  2.71E-02  6.22E-01  1.28E+00  1.7E+00  3.3E-02  2.4E-02  3.0E-02
I135     1 1.47E+00  9.77E-02  1.95E+00  3.76E+01  1.1E+00  2.0E-02  1.4E-02  1.4E-01
X133     0 1.92E-03  1.92E-03 -1.00E+00 -1.00E+00  2.1E-02  6.0E-04  4.3E-04  3.3E-02
Kr85     0 7.32E-04  7.32E-04 -1.00E+00 -1.00E+00  1.6E-03  3.4E-05  2.5E-05  2.5E-03
```

HYSPLIT Simple Configuration Summary

- Emissions must be decay corrected to the time of release
- Multiple species can be tracked in the same simulation
- Decay is applied only during the calculation phase
- Once written to the output file it no longer decays
- Dose conversion factors can be applied to the output
- For total dose, concentration and deposition can be added
- The longer the half-life the lesser the concern about decay

Transfer Coefficient Matrix (TCM) Configuration

- Each emission time is treated as an independent simulation
  - Manually configured (no limits)
  - Automatically configured (one species)
  - A unit source emission rate is required
- Time-varying emissions are treated in the post-processing
- Dose can be computed from multiple radiological species
- Source terms can be computed from measurement data
- This approach permits air concentrations to be recalculated without rerunning the dispersion model as new emission estimates are developed

Multi-File TCM Computational Framework

input | model | output | post-processing

control
namelist
meteorology
→ HYSPLIT → binary → CONDECAY
CONMERGE

TG_{MMDDHH}

- CONDECAY applies time varying source and decay to unit-source dispersion model calculations
- CONMERGE combines all the emission time simulation files into a single output file

The First Two and the Last CONTROL File

```
11 03 14 09
2
37.4206 141.0329 1.0
37.4206 141.0329 100.0
51
0
10000.0
1
/meteorology/wrf_arl/
W03_201103.bin
1
CPAR
1.0
3.0
00 00 00 00 00
1
38.0 140.0
0.05 0.05
20.0 30.0
./
TG_031409
```

```
11 03 14 12
2
37.4206 141.0329 1.0
37.4206 141.0329 100.0
48
0
10000.0
1
/meteorology/wrf_arl/
W03_201103.bin
1
CPAR
1.0
3.0
00 00 00 00 00
1
38.0 140.0
0.05 0.05
20.0 30.0
./
TG_031412
```

```
11 03 16 09
2
37.4206 141.0329 1.0
37.4206 141.0329 100.0
3
0
10000.0
1
/meteorology/wrf_arl/
W03_201103.bin
1
CPAR
1.0
3.0
00 00 00 00 00
1
38.0 140.0
0.05 0.05
20.0 30.0
./
TG_031609
```

CONDECAY processing

HYSPLIT output

TG_031409
TG_031412
TG_031415
TG_mmddhh

CONDECAY
-3:1:11025.8:C137
+ecfactors
+t031106

CONDECAY output

DG_031409
DG_031412
DG_031415
DG_mmddhh

- The emission rate in column 3 (Cs-137) of cfactors.txt is multiplied by species #1 in each TG file
- cfactors.txt should contain an emission rate corresponding with each start time of the TG files
- Decay is set to 11025.8 days and is started at 6Z of March 3rd
- Deposition and air concentration are decayed by default

The CFACTORS.TXT emissions file

YYYY	MM	DD	HH	I131g	I131p	C137p
2011	3	14	9	1.23E+13	1.23E+13	1.86E+12
2011	3	14	12	1.81E+14	1.81E+14	2.86E+13
2011	3	14	15	4.13E+14	4.13E+14	9.00E+13
2011	3	14	18	2.73E+14	2.73E+14	4.15E+13
2011	3	14	21	6.58E+14	6.58E+14	9.54E+13
2011	3	15	0	5.05E+14	5.05E+14	7.29E+13
2011	3	15	3	7.03E+13	7.03E+13	1.00E+13
2011	3	15	6	1.12E+14	1.12E+14	1.58E+13
2011	3	15	9	3.49E+15	2.67E+15	1.35E+14
2011	3	15	12	6.59E+15	2.82E+15	9.28E+13
2011	3	15	15	5.74E+14	2.46E+14	8.00E+12
2011	3	15	18	1.08E+14	4.61E+13	1.49E+12
2011	3	15	21	7.80E+13	7.80E+13	1.04E+13
2011	3	16	0	1.09E+15	1.09E+15	1.44E+14
2011	3	16	3	5.58E+14	5.58E+14	7.27E+13
2011	3	16	6	7.18E+14	7.18E+14	9.06E+13
2011	3	16	9	7.18E+14	7.18E+14	9.06E+13

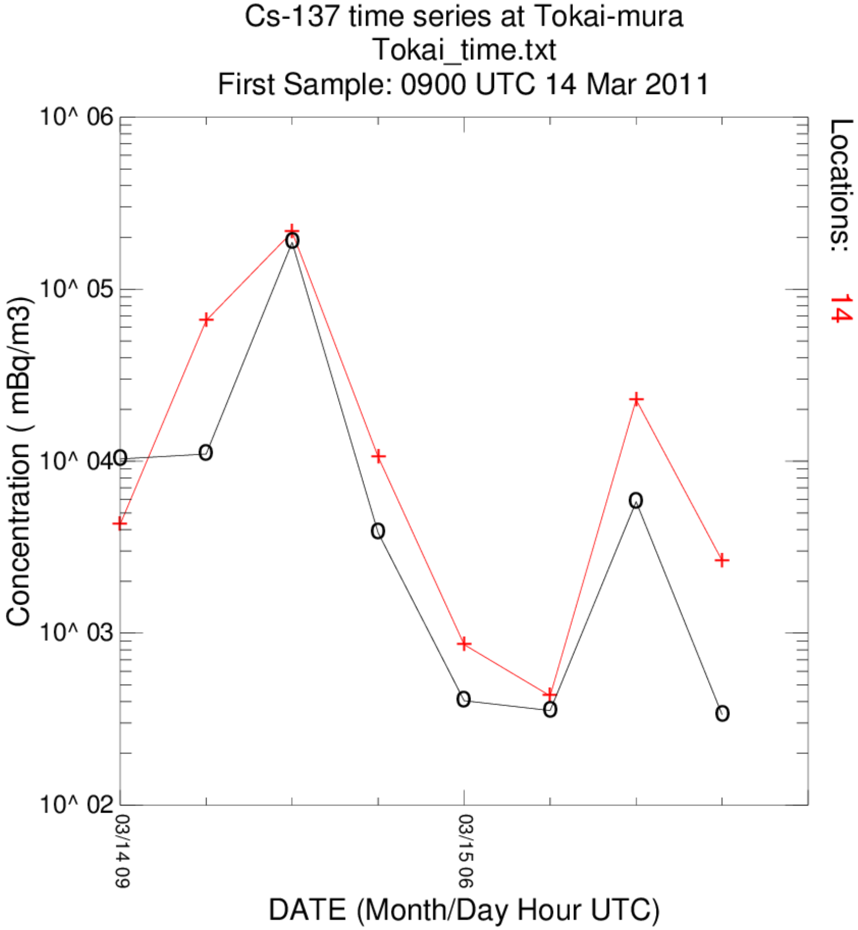
- Selecting the column in CONDECAY determines which species is represented by the HYSPLIT dispersion calculation
- Multiple species can be assigned to the same dispersion calculation

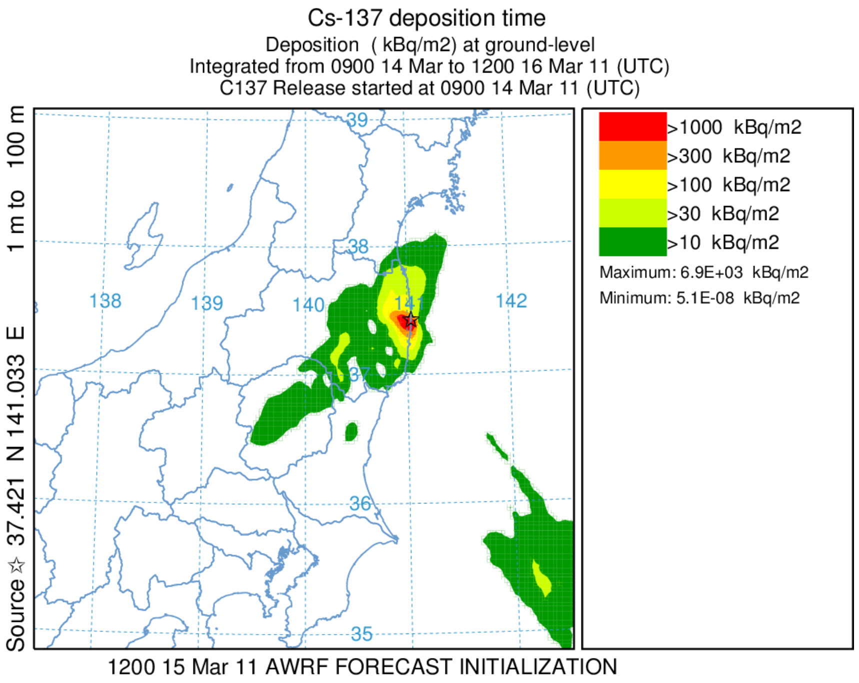
CONMERGE to create a single file

conmerge -imergelist.txt -ofdnpp.bin

Samples ->	1409	1412	1415	1418	1421	1500
DG_031409	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx
DG_031412		xxxx	xxxx	xxxx	xxxx	xxxx
DG_031415			xxxx	xxxx	xxxx	xxxx
DG_031418				xxxx	xxxx	xxxx
DG_031421					xxxx	xxxx
DG_031500						xxxx
mergelist						
fdnpp.bin	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx

Simulation Results using the manual TCM Approach





Single-File TCM Computational Framework

input	model	output	post-processing
control namelist meteorology	HYSPLIT	single binary output file with each release time in its own array	TCMSUM

The current code configuration limits each simulation to a single pollutant species

HYSPLIT input

CONTROL

```
11 03 14 09
2
37.4206 141.0329 1.0
37.4206 141.0329 100.0
51
0
10000.0
1
/meteorology/wrf_arl/
W03_201103.bin
1
CPAR
1.0
3.0
00 00 00 00 00
1
38.0 140.0
0.05 0.05
20.0 30.0
./
fdnpp_tcms.bin
```

SETUP.CFG

```
&SETUP
delt = 5.0,
initd = 0,
khmax = 24,
numpar = -2500,
maxpar = 300000,
efile = '',
krand = 1,
vscales = 5.0,
vscaleu = 200.0,
kmix0 = 150,
rhb = 100,
rht = 80,
qcycle = 3,
ichem = 10,
/
```

An emission cycle consists of a release of one unit per hour for a duration of 3 h

A new emission cycle is started every 3 hours

A concentration array element is created for each emission cycle; the element replaces the species index

TCMSUM processing

HYSPLIT output

fdnpp_tcms.bin

TCMSUM
-ifdnpp_tcms.bin
-ofdnpp
-t031106
-h11025.8
-c3
-scfactors.txt
-pC137

TCMSUM output

fdnpp.bin

decay start time

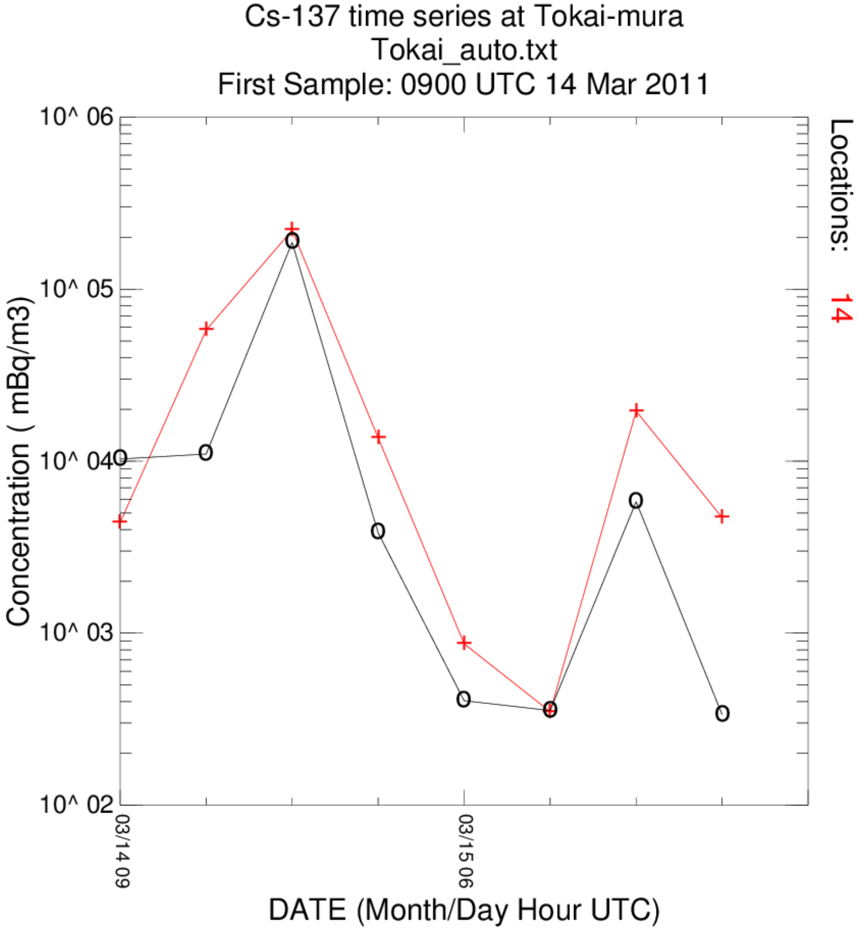
half-life days

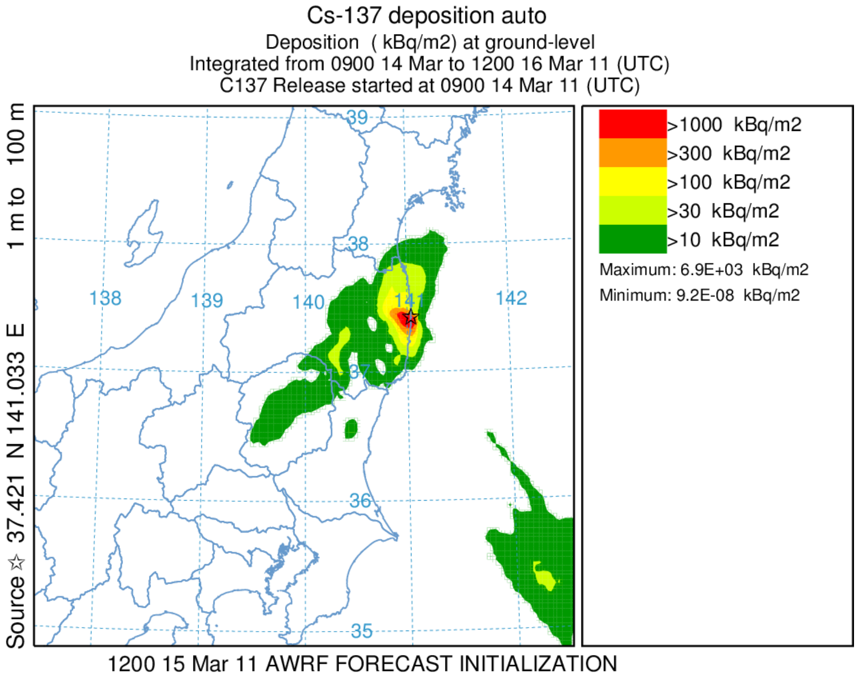
select column 3 of the emissions file

emissions file

4-character pollutant ID label in output file

Simulation Results using automated TCM Approach





Using a Multi-File TCM to Estimate the Emission Rate

input	model	output	post-processing
control namelist meteorology	→ HYSPLIT →	binary TG_{MMDDHH}	→ C2ARRAY TCSOLVE

- C2ARRAY post-processing not yet available for single file TCMs
- TCSOLVE uses singular value decomposition to solve the coefficient matrix

C2ARRAY processing

converts multiple TCM files into a single coefficient matrix (CM)

for the sampling locations defined in JAEA_C137.txt

C2ARRAY
- -imergelist.txt
- -oc2array.csv
- -mJAEA_C137.txt
- -z2

list of unit source input files (TG_*)

comma delimited CM output file

DATEM formatted measured data at Tokai-mura

Process level 2 (air concentration) of the input files

C2ARRAY.CSV

40616.38	40616.5	40616.63	40616.75	40616.88	40617	40617.13	40617.25	40617.38	40617.5	40617.63	40617.75	40617.88	40618	40618.13	40618.25	40618.38	40618.5
1.30E-12	9.79E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.03E+04
1.67E-13	5.85E-13	5.41E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.10E+04
2.06E-13	6.65E-13	1.50E-12	1.47E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.87E+05
0.00E+00	5.27E-15	2.65E-15	1.06E-13	6.08E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.83E+03
4.72E-15	1.03E-14	0.00E+00	1.33E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.05E+02
0.00E+00	6.54E-15	0.00E+00	2.62E-15	1.39E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.35E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.55E+02
0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.80E-14	1.39E-13	3.29E-13	1.64E-13	4.00E-15	5.43E-15	2.25E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.81E+03
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.51E-14	5.88E-14	3.52E-14	2.95E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.36E+02

- Blue column headings time in days from the year 1900
- Red column gives measurement data vector (mBq/m^3)
- Each row gives TCM values for each release (column) time contributing to that measurement (non-zero=yellow)

TCSOLVE solution to the coefficient matrix

- $D_{ij}\ S_i = R_j$
  - concentration at receptor R is the linear sum of all the contributing sources S times the dilution factor D between S and R
- $S_i = (D_{ij})^{-1}\ R_j$
  - the linear relationship between sources and receptors can be expressed by the inverse of the coefficient matrix

TCSOLVE

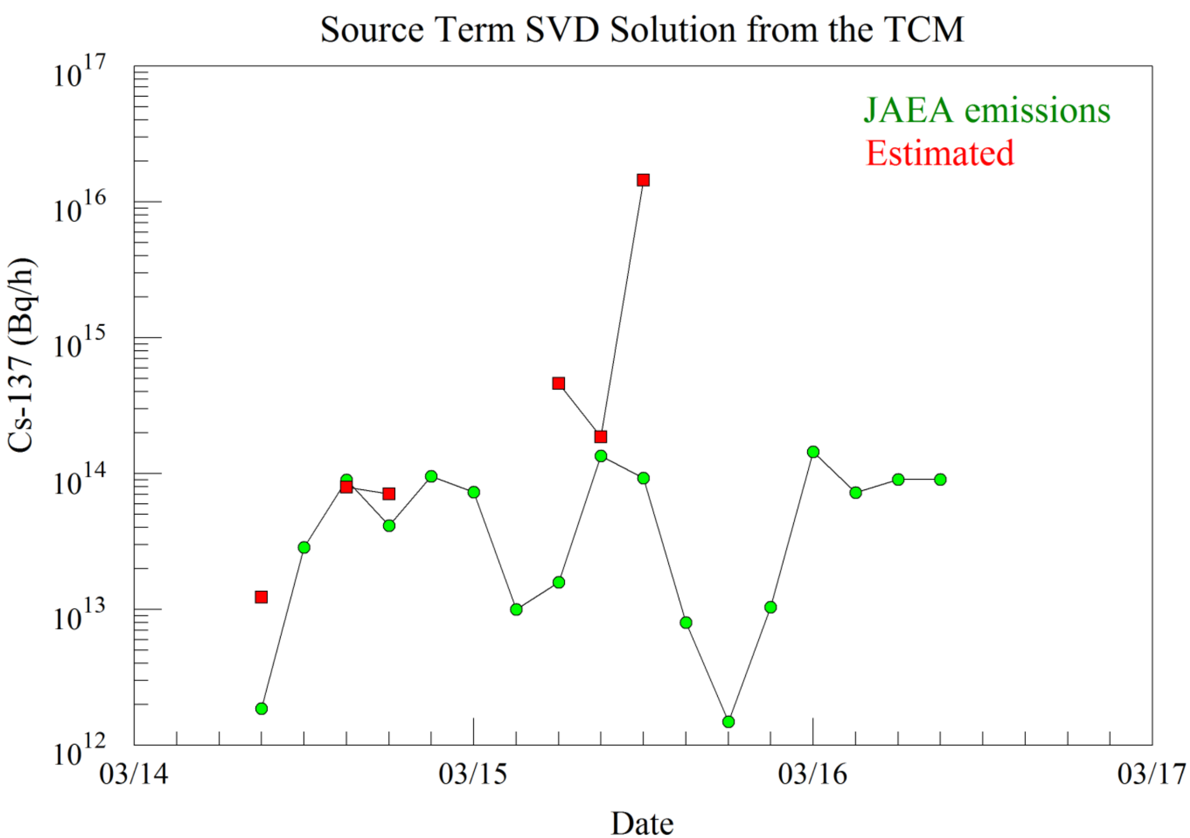
-ic2array.csv	input CM array (D = Bq/m^3)
-u0.001	convert R from mBq to Bq
-otcsolve.txt	source term solution in Bq

Alternate Approach:

- Edit the CM file into a square matrix
- Use EXCEL functions MINVERSE() and MMULT()

TCSOLVE.TXT

Date,	Result,
40616.375,	1.228E+13,
40616.500,	-5.789E+13,
40616.625,	7.914E+13,
40616.750,	7.092E+13,
40616.875,	-5.909E+13,
40617.000,	-8.441E+14,
40617.125,	-6.363E+13,
40617.250,	4.623E+14,
40617.375,	1.867E+14,
40617.500,	1.448E+16,
40617.625,	-3.417E+14,
40617.750,	0.000E+00,
40617.875,	0.000E+00,
40618.000,	0.000E+00,
40618.125,	0.000E+00,
40618.250,	0.000E+00,
40618.375,	0.000E+00,



HYSPLIT Transfer Coefficient Matrix Summary

- Emissions must be decay corrected to the same time
- One simulation per emission time period
- Time-varying emissions are applied during post-processing
- Decay is applied during the post-processing phase
  - For both air concentration and deposition
- Post-processing permits a single computational species to represent multiple radionuclides
  - Depositing particles
  - Depositing gases
  - Noble gases without deposition
  - Gravitational settling

Dose Calculations Combining Multiple Radionuclides

- Simple approach: single time period constant unit dispersion and multiple species emissions combined to compute total dose
  - Computational footnote: a nuclear detonation
- Complex approach: multiple time period constant unit dispersion files and time-varying multiple species emissions combined to compute total dose

All the following examples show dose rate but a simple command line flag converts output to accumulated dose

Dose Calculations using Constant Unit Emission

CONTROL file

```
2
RNUC
1.0
51.0
00 00 00 00 00
NGAS
1.0
51.0
00 00 00 00 00
1
38.0 140.0
0.05 0.05
20.0 30.0
./
fdnpp_unit.bin
2
0 100
00 00 00 00 00
00 00 00 00 00
00 03 00
2
1.0 1.0 1.0
0.001 0.0 0.0 0.0 0.0
0.0 8.0E-05 8.0E-05
0.0
0.0
0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0
0.0
0.0
```

activity.txt file

Mass	Nucl	T1/2	Emission	Cloudshine	Groundshine	Inhalation
Hr=	0.00	sec	Bq	rem/h Bq/m3	rem/h Bq/m2	rem/Bq
95	Nb	3.02000E+06	1.62000E+13	1.26000E-08	2.62000E-10	2.38000E-06
110	Ag	2.18000E+07	6.48000E+12	4.57000E-08	9.29000E-10	2.38000E-06
132	Te	2.82000E+05	1.62000E+16	3.36000E-09	7.63000E-11	7.38000E-07
131	I	6.94656E+05	8.10000E+15	6.08400E-09	1.31040E-10	7.38000E-07
133	I	7.49000E+04	8.10000E+15	9.94000E-09	2.22000E-10	7.38000E-07
133	Xe	4.52995E+05	3.66000E+17	5.00400E-10	0.00000E+00	0.00000E+00
134	Cs	6.50000E+07	8.10000E+14	2.54000E-08	5.33000E-10	4.63000E-07
137	Cs	9.52093E+08	8.10000E+14	3.34080E-11	1.07640E-12	4.63000E-07
140	Ba	1.10160E+06	4.05000E+13	2.90520E-09	6.84000E-11	1.03000E-07
140	La	1.44979E+05	4.05000E+13	3.99600E-08	7.77600E-10	1.07000E-07

→ HYSPLIT →

CON2REM: unit dispersion to dose

-ifdnpp_unit.bin -ofdnpp_dose.bin

NGAS= ^{133}Xe + ^{85}Kr + …

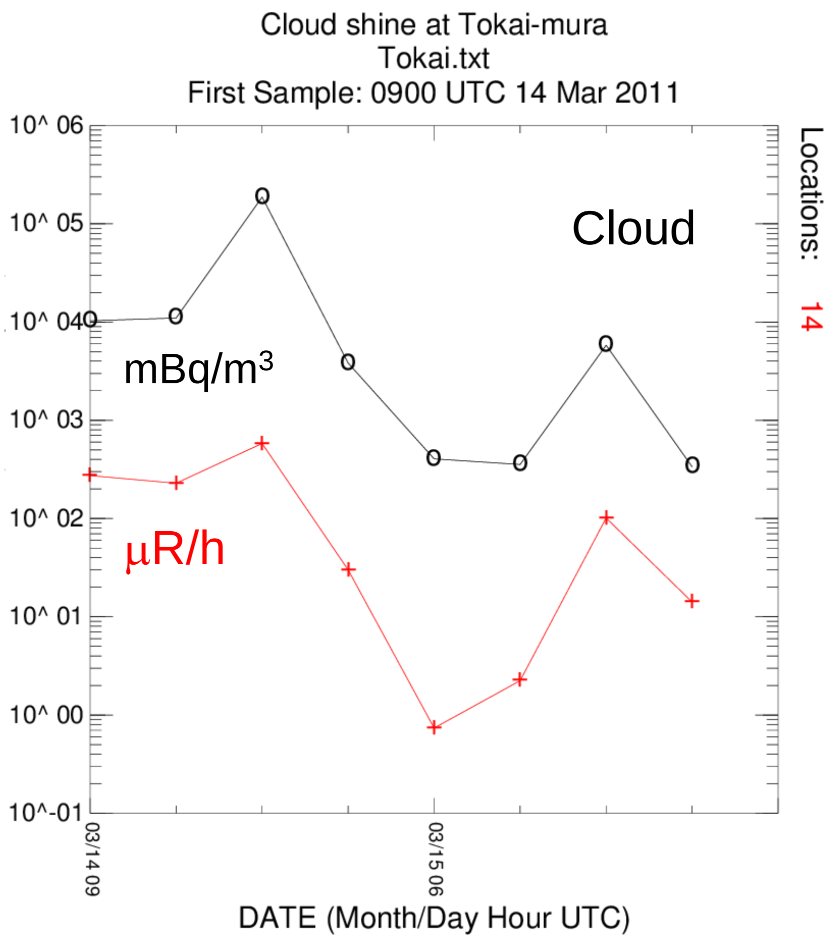
RNUC= ^{95}Nb + ^{110}Ag + …

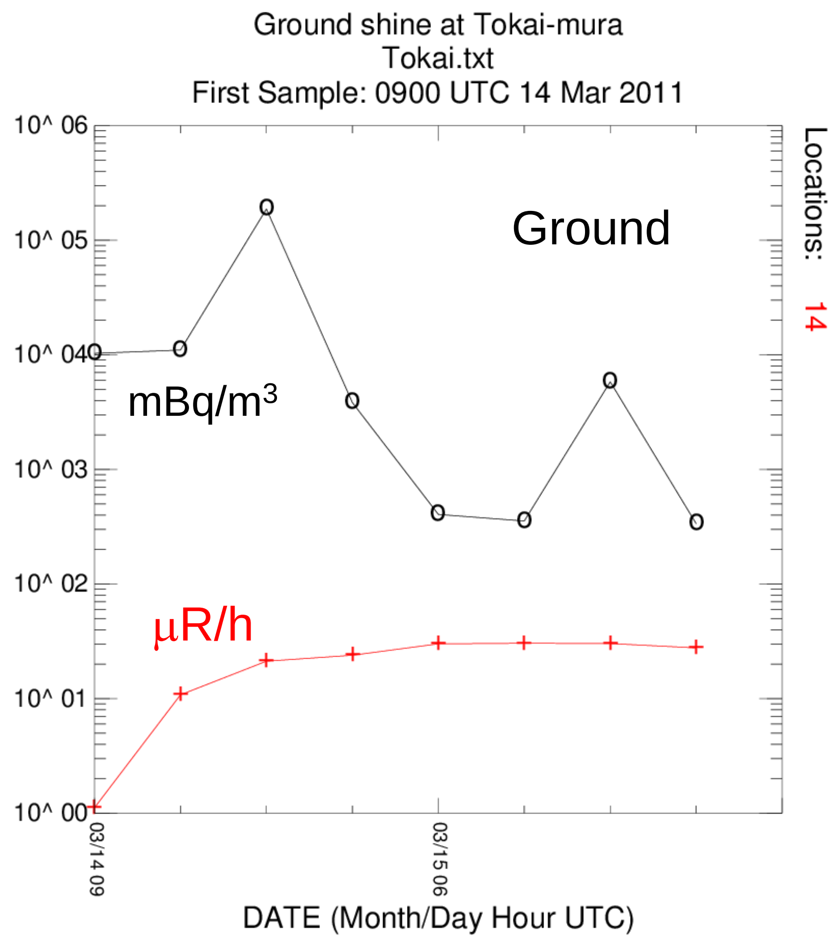
CONCSUM: ground and cloud-shine

-ifdnpp_dose.bin -ofdnpp_sums.bin -L -pDOSE

Dose Rates at Tokai-Mura

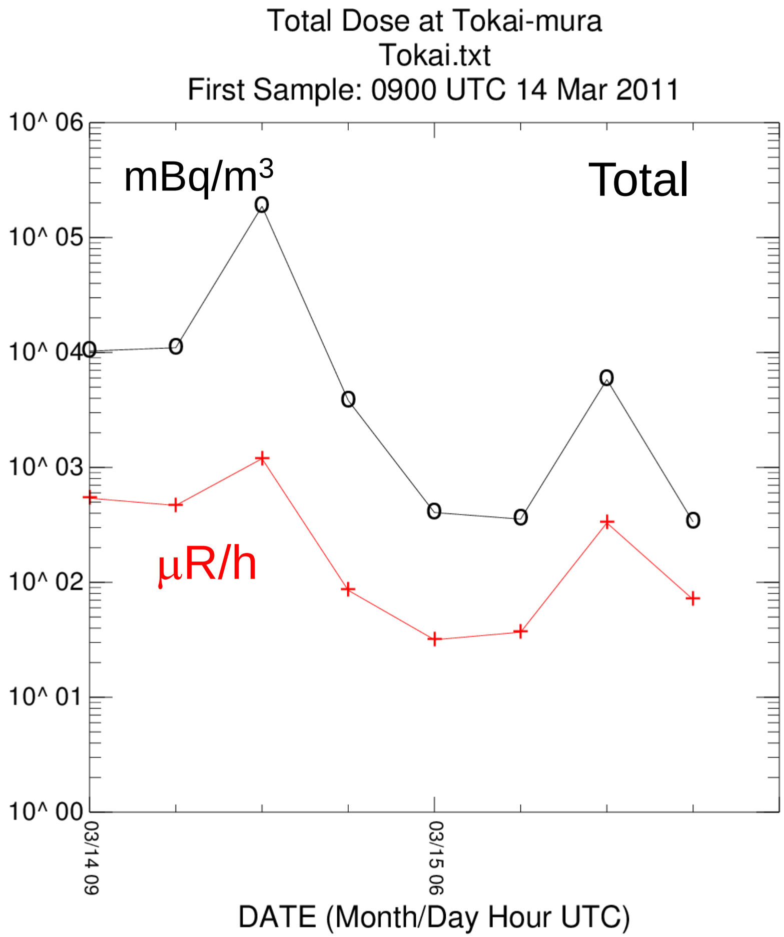
using the maximum rate for each of 10 radioncuclides

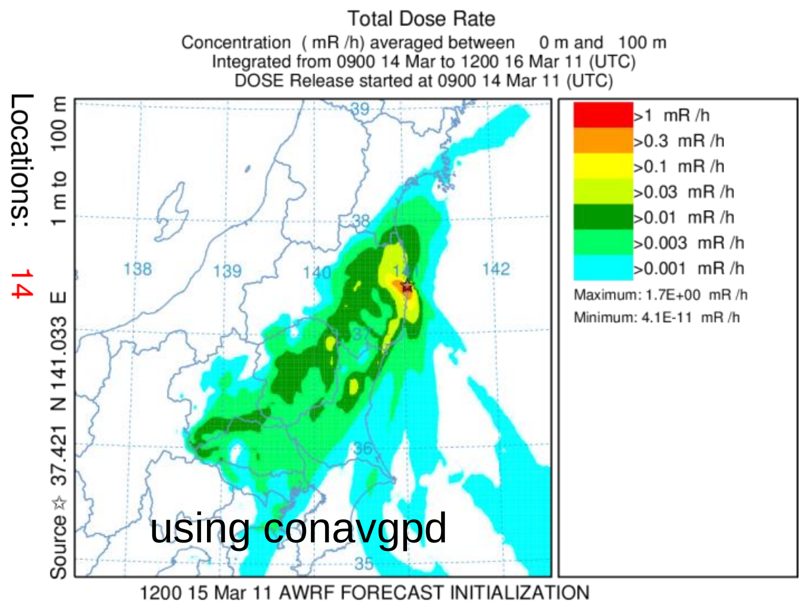




Dose Rates at Tokai-Mura

using the maximum rate for each of 10 radionculides





ACTIVITY.TXT file at the initial time of fission

Mass	Nucl	T1/2	U235H	U235T	Pu239H	Pu239T	Cloudshine	Groundshine
Hr=	0.00	sec	Bq	Bq	Bq	Bq	rem/h Bq/m3	rem/h Bq/m2
66	Ni	1.96560E+05	1.32028E+12	3.30528E+08	2.82852E+11	1.00396E+09	3.81600E-12	1.01880E-14
66	Cu	3.06000E+02	8.48086E+14	2.12610E+11	1.83457E+14	6.50788E+11	1.76040E-09	7.30800E-11
67	Cu	2.22912E+05	2.44159E+12	1.45929E+09	3.96960E+11	1.81098E+09	1.76400E-09	3.78000E-11
67	Ga	2.81750E+05	5.72476E+04	0.00000E+00	2.11400E+05	0.00000E+00	2.33640E-09	5.07600E-11
68	Ga	4.08360E+03	1.46519E+08	0.00000E+00	4.89867E+08	4.50148E+05	1.54440E-08	3.59640E-10
69	Zn-m	4.95360E+04	8.98617E+10	1.92821E+07	8.67693E+10	1.27516E+09	6.62400E-09	1.43280E-10
69	Zn	3.36000E+03	3.54000E+14	4.21046E+11	9.94955E+13	1.57959E+12	7.16400E-11	7.48800E-12
69	Ge	1.41120E+05	2.96916E+04	0.00000E+00	2.43279E+05	0.00000E+00	1.43640E-08	3.02040E-10
70	Ga	1.26600E+03	2.54811E+11	1.04629E+07	4.37022E+11	5.53039E+09	3.02400E-10	3.05280E-11
71	Zn-m	1.42920E+04	1.64557E+13	2.07430E+10	9.89864E+12	3.93424E+11	2.51640E-08	5.54400E-10
72	Zn	1.67400E+05	3.21357E+13	1.42646E+11	1.14655E+13	6.40561E+11	2.22120E-09	4.82400E-11
72	Ga	5.07600E+04	1.06689E+14	4.70428E+11	3.86993E+13	2.14799E+12	4.71600E-08	8.92800E-10
72	As	9.36000E+04	7.41282E+05	0.00000E+00	7.10476E+06	1.58846E+04	2.97360E-08	6.51600E-10
73	Ga	1.75320E+04	5.80785E+14	5.24249E+12	1.92739E+14	1.34660E+13	5.00400E-09	1.20600E-10
73	As	6.93792E+06	4.98736E+05	0.00000E+00	2.68850E+06	1.85727E+04	5.58000E-11	1.86480E-12
74	As	1.53446E+06	6.22469E+07	9.74810E+03	2.27260E+08	3.96971E+06	1.22400E-08	2.68920E-10
75	Ge	4.96800E+03	4.89724E+15	1.94076E+14	1.85007E+15	2.48489E+14	6.40800E-10	2.59200E-11
75	Se	1.03507E+07	1.04467E+05	0.00000E+00	8.70559E+05	7.88726E+03	6.04800E-09	1.29960E-10
76	As	9.46800E+04	3.05503E+11	1.57034E+09	5.75792E+11	5.26303E+10	7.41600E-09	1.88640E-10
167	Ho	1.11600E+04	1.49374E+13	1.99435E+10	2.16391E+13	1.22729E+12	5.72400E-09	1.26360E-10
167	Tm	7.98336E+05	9.71821E+05	0.00000E+00	6.25306E+07	0.00000E+00	1.94040E-09	4.71600E-11
169	Er	8.12160E+05	8.65410E+10	2.64061E+07	7.05642E+10	1.63096E+09	1.06920E-11	2.43000E-14
169	Yb	2.76653E+06	1.86633E+04	0.00000E+00	1.00971E+06	0.00000E+00	4.06800E-09	1.00080E-10
170	Tm	1.11110E+07	1.11105E+07	0.00000E+00	1.32191E+08	3.67377E+03	1.32120E-10	9.50400E-12
171	Er	2.70720E+04	5.75830E+11	7.82197E+07	1.09175E+12	5.22574E+09	5.90400E-09	1.38600E-10
171	Tm	6.05906E+07	2.61744E+08	0.00000E+00	5.44308E+08	2.33487E+06	6.37200E-12	1.99800E-13
172	Er	1.77120E+05	7.88557E+10	3.90717E+06	7.02070E+10	2.48777E+08	8.24400E-09	1.78560E-10
172	Tm	2.28960E+05	6.49371E+10	3.02646E+06	7.12341E+10	1.94418E+08	8.28000E-09	1.75320E-10
172	Lu	5.78880E+05	4.79436E+04	0.00000E+00	3.23775E+06	0.00000E+00	3.11040E-08	6.33600E-10

CONTROL and EMISSIONS for a nuclear detonation

CONTROL

```
10 05 19 09
6
39.7697 -86.1498 1000.0
39.7697 -86.1498 2000.0
39.7697 -86.1498 3000.0
39.7697 -86.1498 4000.0
39.7697 -86.1498 5000.0
39.7697 -86.1498 6000.0
06
0
10000.0
1
C:/hysplit4/working/
hysplit.t06z.namf
3
P005
0.0
0.1
00 00 00 00 00
P010
0.0
0.1
00 00 00 00 00
P015
0.0
0.1
00 00 00 00 00
1
0.0 0.0
0.01 0.01
3.0 3.0
./
cdump
2
0 100
00 00 00 00 00
00 00 00 00 00
00 01 00
3
1.0 1.0 1.0
0.44 0.0 0.0 0.0 0.0
0.0 0.0 0.0
0.0
0.0
1.0 1.0 1.0
0.23 0.0 0.0 0.0 0.0
0.0 0.0 0.0
0.0
0.0
1.0 1.0 1.0
0.15 0.0 0.0 0.0 0.0
0.0 0.0 0.0
0.0
0.0
```

EMITIMES

```
YYYY MM DD HH    DURATION(hhhh) #RECORDS
YYYY MM DD HH MM DURATION(hhmm) LAT LON HGT(m) RATE(/h) AREA(m2) HEAT(w)
2010 05 19 09 9999 18
2010 05 19 09 00 0006 39.7697 -86.1498 1000.0 0.2 0.0 0.0
2010 05 19 09 00 0006 39.7697 -86.1498 1000.0 0.1 0.0 0.0
2010 05 19 09 00 0006 39.7697 -86.1498 1000.0 0.0 0.0 0.0
2010 05 19 09 00 0006 39.7697 -86.1498 2000.0 0.5 0.0 0.0
2010 05 19 09 00 0006 39.7697 -86.1498 2000.0 0.1 0.0 0.0
2010 05 19 09 00 0006 39.7697 -86.1498 2000.0 0.0 0.0 0.0
2010 05 19 09 00 0006 39.7697 -86.1498 3000.0 1.2 0.0 0.0
2010 05 19 09 00 0006 39.7697 -86.1498 3000.0 0.2 0.0 0.0
2010 05 19 09 00 0006 39.7697 -86.1498 3000.0 0.1 0.0 0.0
2010 05 19 09 00 0006 39.7697 -86.1498 4000.0 2.5 0.0 0.0
2010 05 19 09 00 0006 39.7697 -86.1498 4000.0 0.2 0.0 0.0
2010 05 19 09 00 0006 39.7697 -86.1498 4000.0 0.1 0.0 0.0
2010 05 19 09 00 0006 39.7697 -86.1498 5000.0 2.5 0.0 0.0
2010 05 19 09 00 0006 39.7697 -86.1498 5000.0 0.2 0.0 0.0
2010 05 19 09 00 0006 39.7697 -86.1498 5000.0 0.1 0.0 0.0
2010 05 19 09 00 0006 39.7697 -86.1498 6000.0 1.7 0.0 0.0
2010 05 19 09 00 0006 39.7697 -86.1498 6000.0 0.2 0.0 0.0
2010 05 19 09 00 0006 39.7697 -86.1498 6000.0 0.1 0.0 0.0
```

Fission and Dose References for CON2REM

- The radionculide yield per 100 fissions was taken from: T.R. England and B.F. Rider, Los Alamos National Laboratory, LA-UR-94-3106; ENDF-349 (1993) digitally tabulated and available from http://ie.lbl.gov/fission.html
- Not part of the HYSPLIT distribution, but an activity.txt file can be created for any time after the time of fission using England and Rider
- Radionuclide inventories were computed using the rate of 1.45E+23 fissions per kT for nuclear detonations.
- For thermal reactions we assume 3000 MW-hours equals 2.58 kT
- The external dose rate for cloud- and ground-shine is computed from the factors given by Eckerman K.F. and Leggett R.W. (1996) DCFPAK: Dose coefficient data file package for Sandia National Laboratory, Oak Ridge National Laboratory Report ORNL/TM-13347

Dose from Time-Varying Unit Emission Files

TG_mmddhh → CG_mmddhh → DG_mmddhh → SG_mmddhh → dose.bin

\+ cfactors.txt

\+ activity.txt

\+ mergelist.txt

CONDECAY

CON2REM

CONCSUM

CONMERGE

creates an concentration array element for each species on command line

Converts concentration to dose for each species assuming no decay and a unit emission

Adds dose for air and ground and species to obtain total dose for each release time

CONDECAY processing

```
CONDECAY
  -1:1:11025.8:C137
  -3:1:8.02330:I131
  -4:1:754.020:C134
  -5:1:0.86958:I133
  -6:1:1.10167:B140
  -7:1:1.44980:L140
  -8:1:3.23000:T132
  -9:1:2.18000:A110
  -10:1:3.0200:NB95
  -14:1:5.2474:X133
  +ecfactors
  +oCG_
  +t031106
```

cfactors.txt

YYYY	MM	DD	HH	Cs-137	I-131g
	I-131p	Cs-134	I-133	Ba-140	La-140
	Te-132	Ag-110m	Nb-95	Mo-99	Tc-99m
	Sn-113	Xe-133			
2011	3	14	9	4.30E+12	2.15E+13
	2.15E+13	4.30E+12	4.30E+13	2.15E+11	2.15E+11
	8.60E+13	3.44E+10	8.60E+10	4.30E+12	4.30E+12
	2.58E+10	8.71E+15			
2011	3	14	12	1.10E+14	5.50E+14
	5.50E+14	1.10E+14	1.10E+15	5.50E+12	5.50E+12
	2.20E+15	8.80E+11	2.20E+12	1.10E+14	1.10E+14
	6.60E+11	1.01E+16			
2011	3	14	15	4.00E+13	2.00E+14
	2.00E+14	4.00E+13	4.00E+14	2.00E+12	2.00E+12
	8.00E+14	3.20E+11	8.00E+11	4.00E+13	4.00E+13
	2.40E+11	1.11E+16			
2011	3	14	18	1.20E+13	6.00E+13
	6.00E+13	1.20E+13	1.20E+14	6.00E+11	6.00E+11
	2.40E+14	9.60E+10	2.40E+11	1.20E+13	1.20E+13
	7.20E+10	2.90E+17			
2011	3	14	21	8.10E+14	4.05E+15
	4.05E+15	8.10E+14	8.10E+15	4.05E+13	4.05E+13
	1.62E+16	6.48E+12	1.62E+13	8.10E+14	8.10E+14
	4.86E+12	3.66E+17			
2011	3	15	0	1.10E+14	4.84E+14
	4.84E+14	1.10E+14	9.68E+14	5.50E+12	5.50E+12
	2.20E+15	8.80E+11	2.20E+12	1.10E+14	1.10E+14
	6.60E+11	1.97E+17			
2011	3	15	3	2.70E+14	1.19E+15
	1.19E+15	2.70E+14	2.38E+15	1.35E+13	1.35E+13
	5.40E+15	2.16E+12	5.40E+12	2.70E+14	2.70E+14
	1.62E+12	1.28E+17			

CON2REM and CONCSUM processing

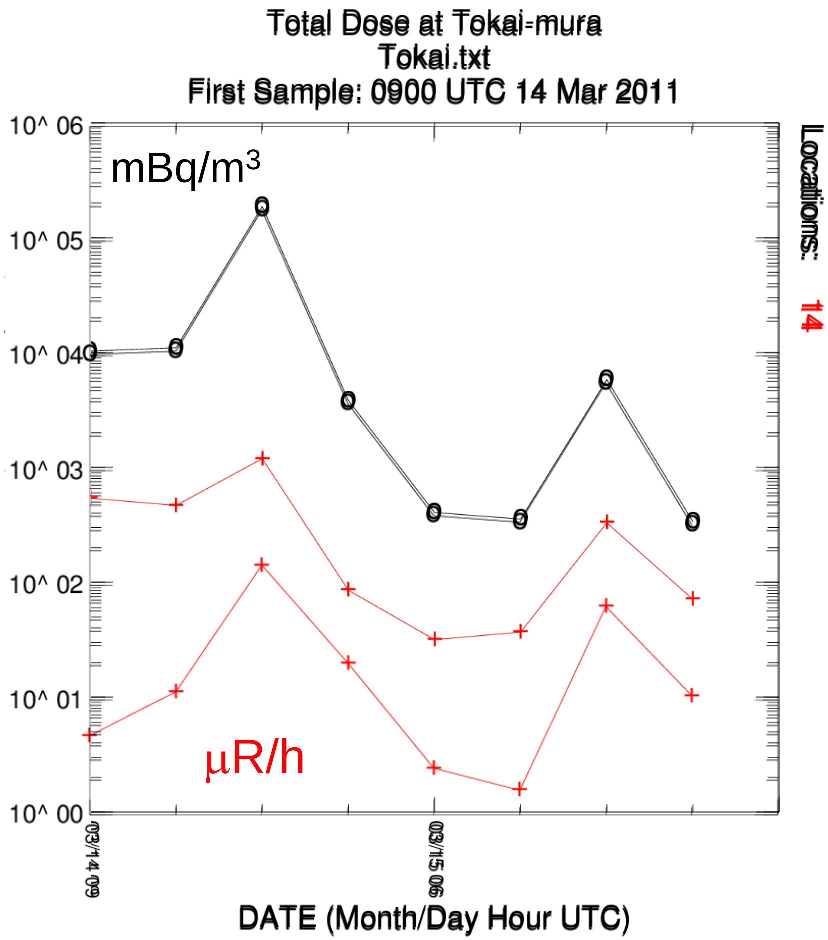
```
for %%H in (1409 1412 1415 1418
1421 1500 1503 1506 1509 1512 1515
1518 1521 1600 1603 1606 1609) do (

CON2REM
 -iCG_03%%H
 -oDG_03%%H
 -s1                    match to input
 -t0                    no decay

CONCSUM
 -iDG_03%%H
 -oSG_03%%H -l
 -pDOSE                 label output
)

CONMERGE -imergelist.txt -ofdnpp.bin
```

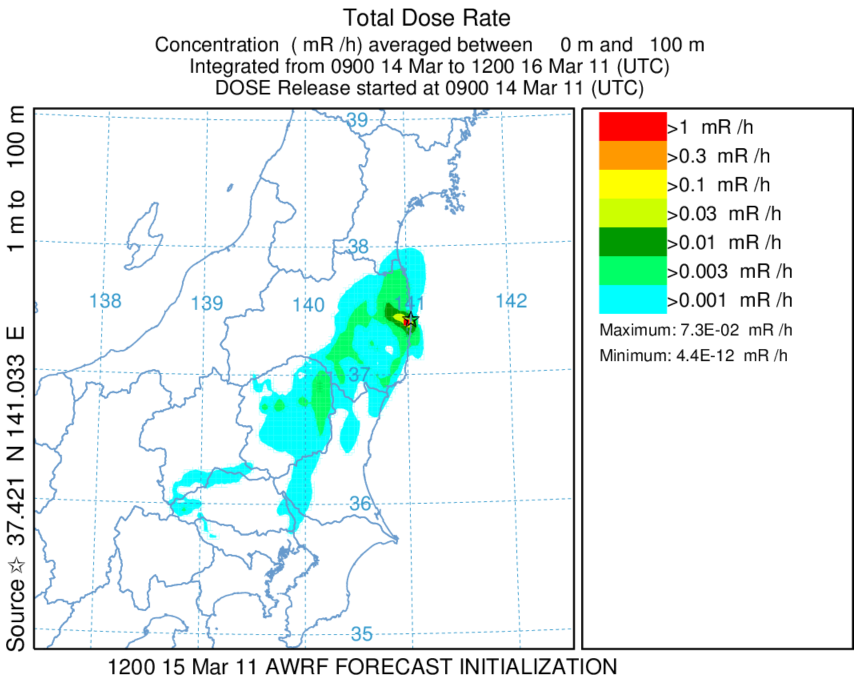
activity.txt: note that all emissions = 1.0

```
Mass Nucl        T1/2   Emissions Cloudshine Groundshine Inhalation
Hr=   0.00        sec          Bq rem/h Bq/m3 rem/h Bq/m2   rem/Bq
0001 NB95  3.02000E+06 1.00000E+00 1.26000E-08 2.62000E-10 2.38000E-06
0002 A110  2.18000E+07 1.00000E+00 4.57000E-08 9.29000E-10 2.38000E-06
0003 T132  2.82000E+05 1.00000E+00 3.36000E-09 7.63000E-11 7.38000E-07
0004 I131  6.94656E+05 1.00000E+00 6.08400E-09 1.31040E-10 7.38000E-07
0005 I133  7.49000E+04 1.00000E+00 9.94000E-09 2.22000E-10 7.38000E-07
0006 X133  4.52995E+05 1.00000E+00 5.00400E-10 0.00000E+00 0.00000E+00
0007 C134  6.50000E+07 1.00000E+00 2.54000E-08 5.33000E-10 4.63000E-07
0008 C137  9.52093E+08 1.00000E+00 3.34080E-11 1.07640E-12 4.63000E-07
0009 B140  1.10160E+06 1.00000E+00 2.90520E-09 6.84000E-11 1.03000E-07
0010 L140  1.44979E+05 1.00000E+00 3.99600E-08 7.77600E-10 1.07000E-07
```

- The 4-character radionuclide label in the activity.txt file must match the input species ID in the CG_* input file created by the command line options of condecay.

Final Dose using Time-Varying TCM Approach





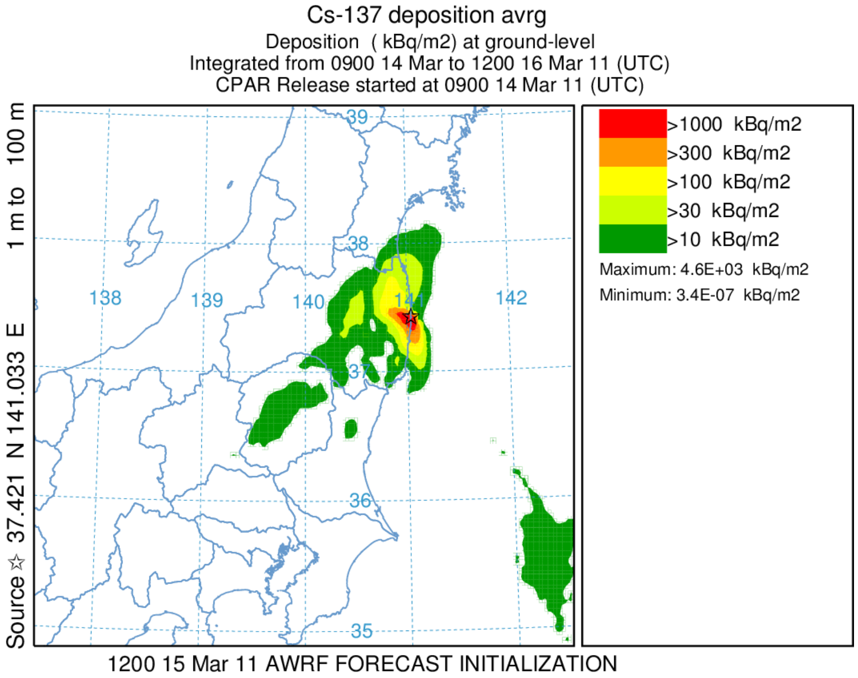
Summary

- Current distribution: *condecay, con2rem, conavgpd, concsum, conmerge, c2array, tcsolve*
- Source code only: *con2dose*
- October 2014 distribution:
  - *tcmsum*
  - Revised wet deposition (Fukushima optimized)
- Other relevant applications not discussed
  - Time-of-arrival products (*isochron*)
  - Peak values (*conmaxv*)
  - Use the web interface to configure local version
- The TCM approach avoids the requirement for a new simulation for each source term variation

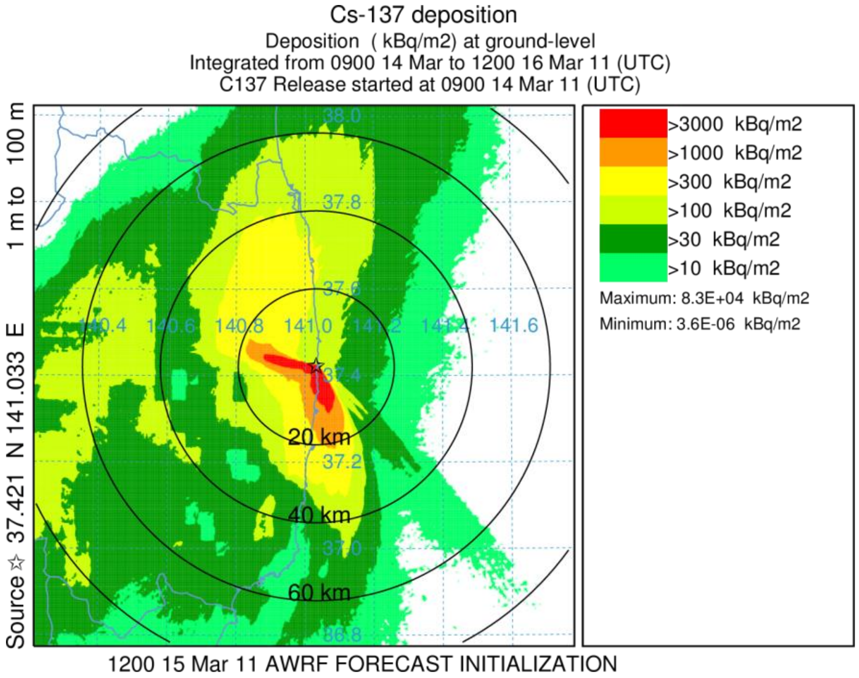
^{137}Cs Deposition Example Standard and Fine Resolution

The fine grid will always show higher values near the source!

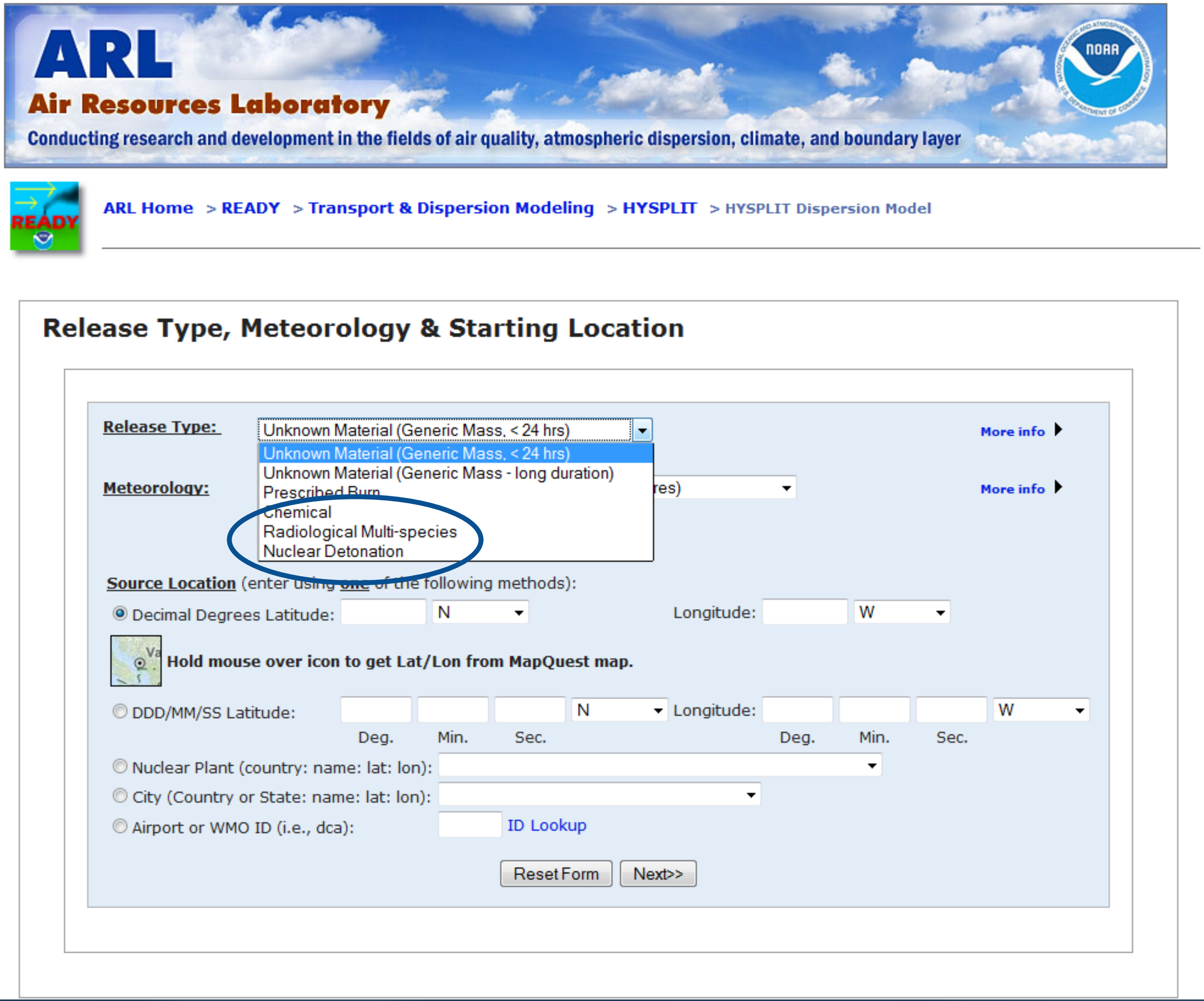
0.05 degree grid



0.005 degree grid



Through the WEB: https://ready.arl.noaa.gov/hyreg-bin/dispsrc.pl



ARL
Air Resources Laboratory
Conducting research and development in the fields of air quality, atmospheric dispersion, climate, and boundary layer

READY

ARL Home > READY > Transport & Dispersion Modeling > HYSPLIT > HYSPLIT Dispersion Model

Release Type, Meteorology & Starting Location

Release Type: Unknown Material (Generic Mass, < 24 hrs) More info

Unknown Material (Generic Mass, < 24 hrs)
Unknown Material (Generic Mass - long duration)
Prescribed Burn
Chemical
Radiological Multi-species
Nuclear Detonation

Meteorology: res) More info

Source Location (enter using one of the following methods):

Decimal Degrees Latitude: N Longitude: W

Hold mouse over icon to get Lat/Lon from MapQuest map.

DDD/MM/SS Latitude: Deg. Min. Sec. N Longitude: Deg. Min. Sec. W

Nuclear Plant (country: name: lat: lon):

City (Country or State: name: lat: lon):

Airport or WMO ID (i.e., dca): ID Lookup

Reset Form Next>>