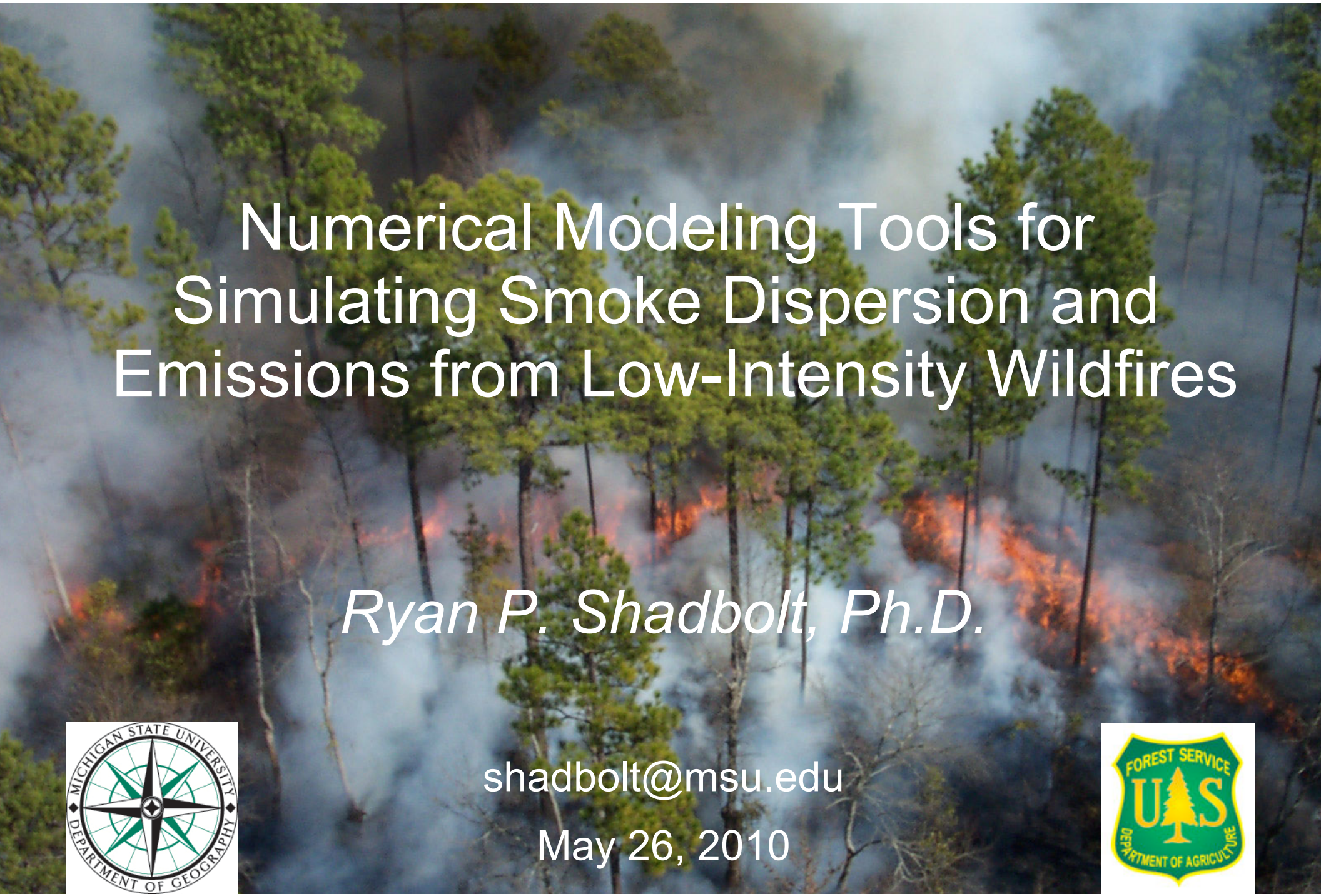


Numerical Modeling Tools for Simulating Smoke Dispersion and Emissions from Low-Intensity Wildfires

Ryan P. Shadbolt, Ph.D.

shadbolt@msu.edu

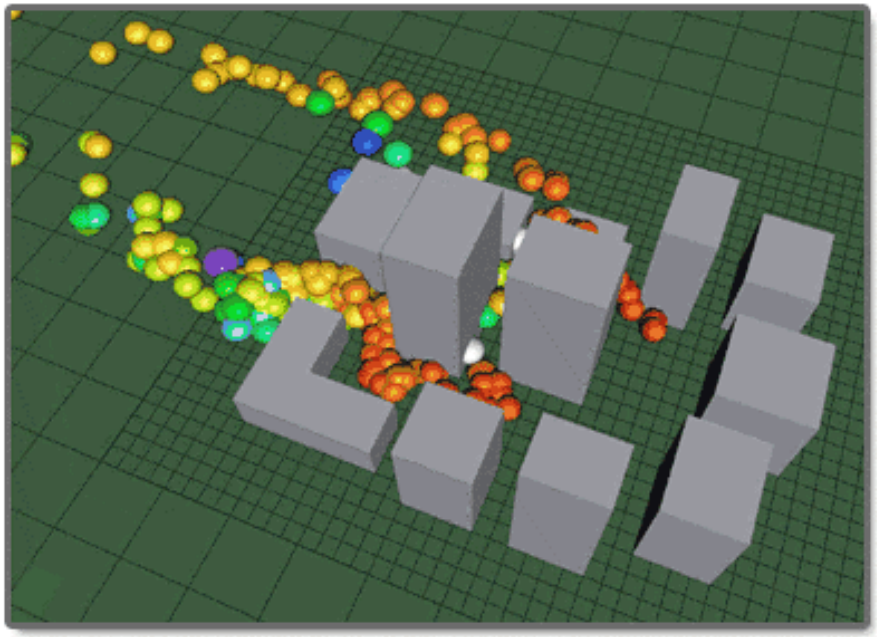
May 26, 2010

Models Explored

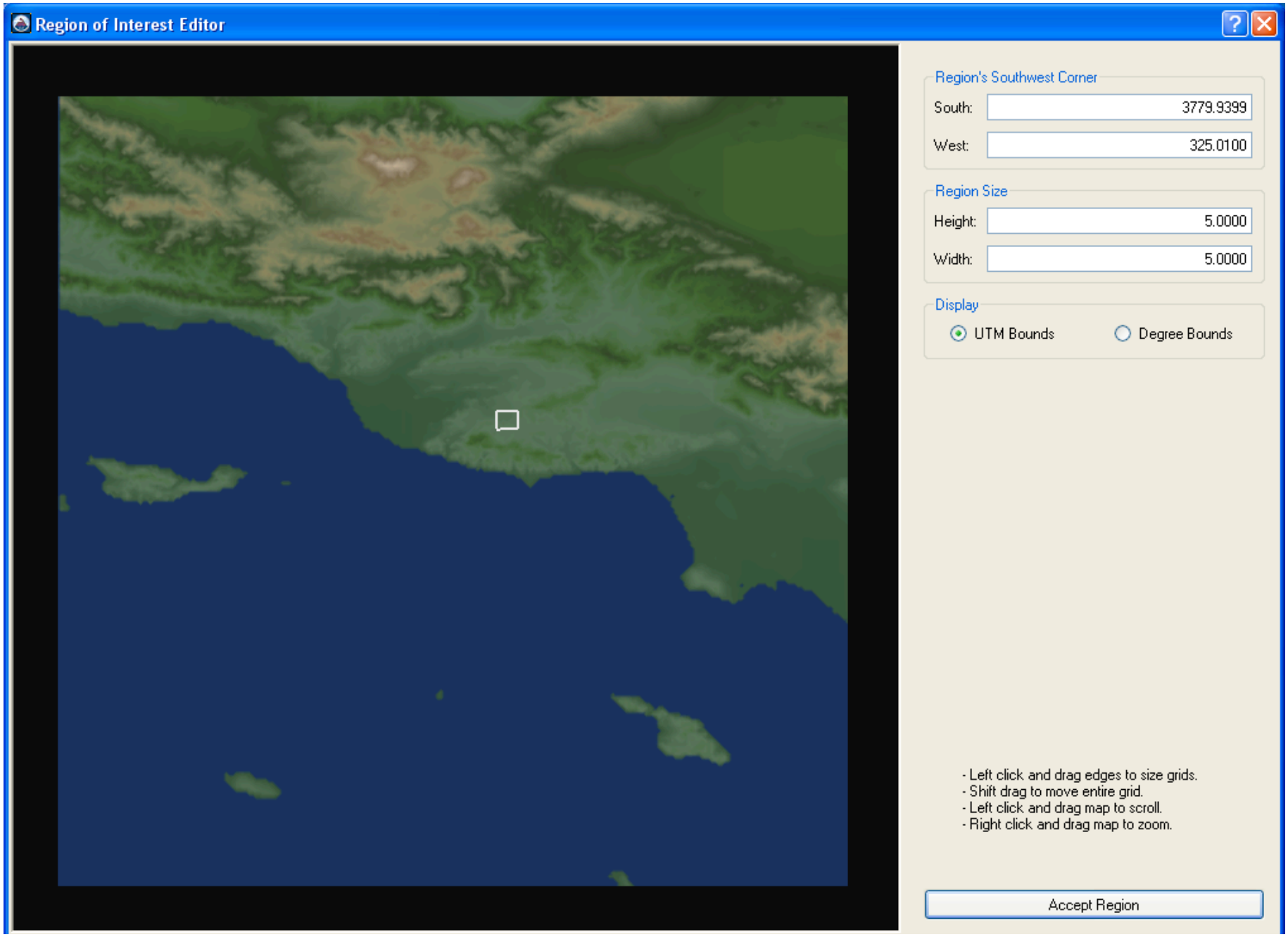
Regional climate models: ARPS, WRF, A2C

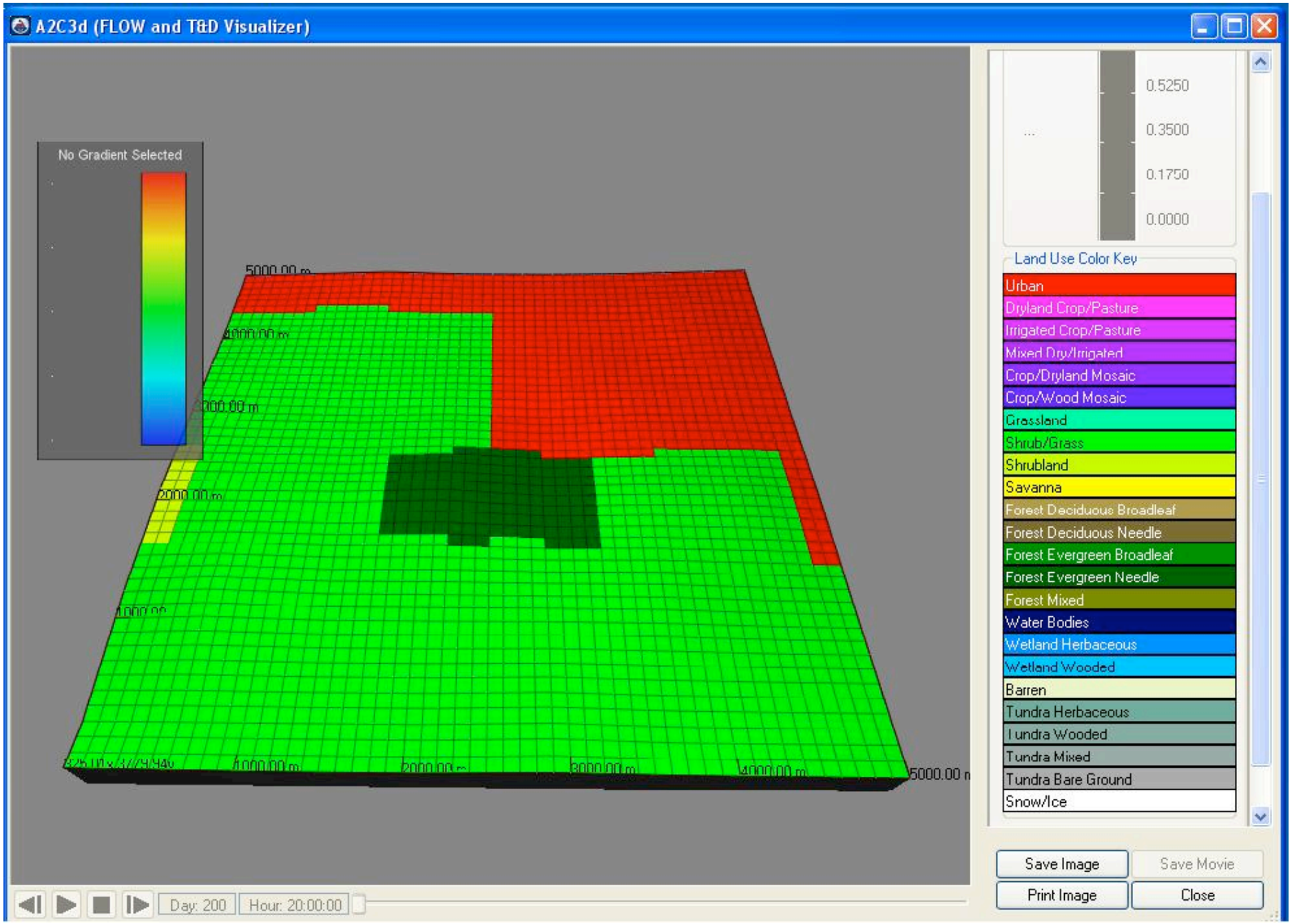
Smoke transport and emission tools:
FLEXPART, RAFLES, A2C, BlueSky, Natural Fuels Photo Series, FCCS, Consume, FEPS

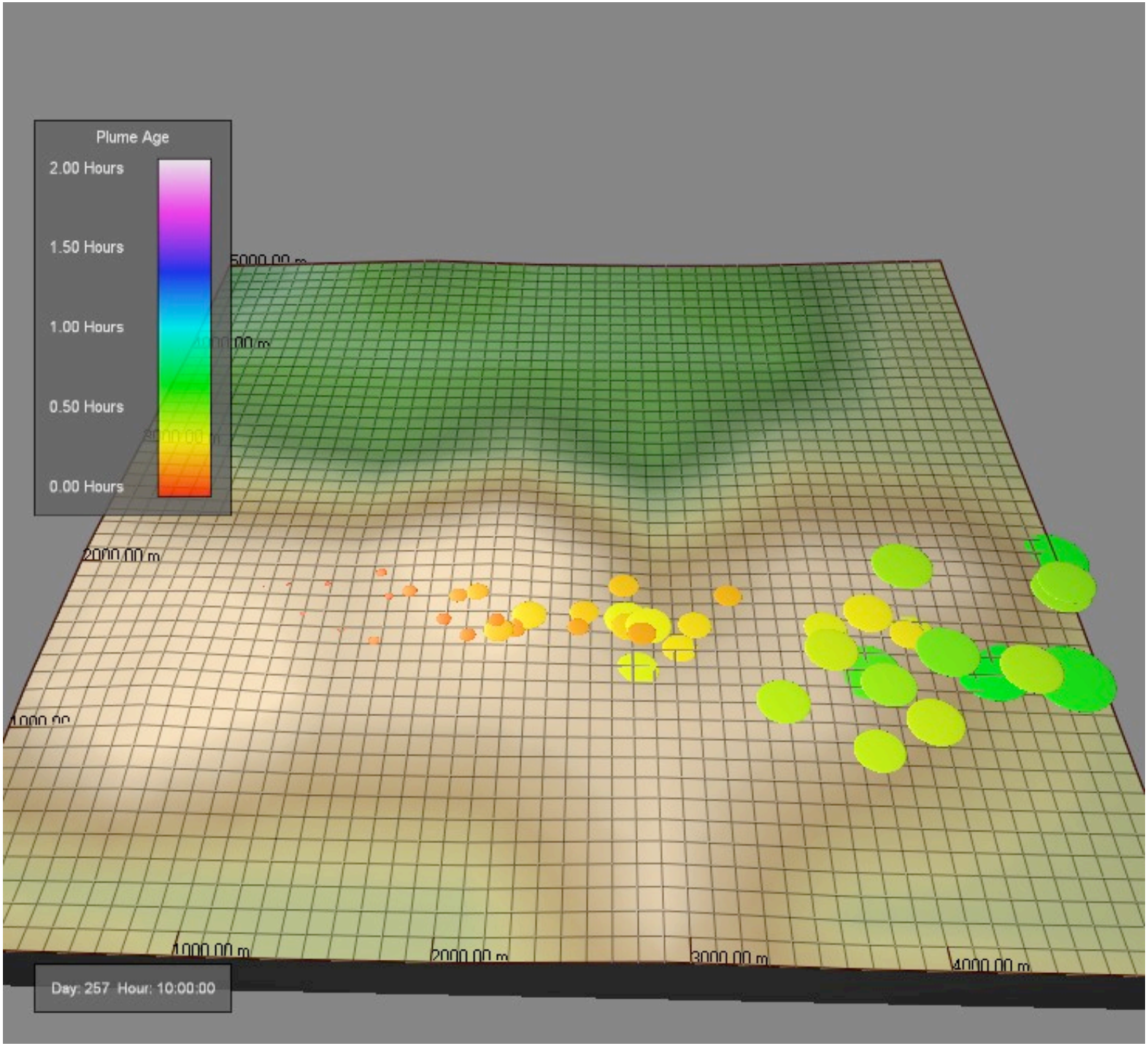
A2C



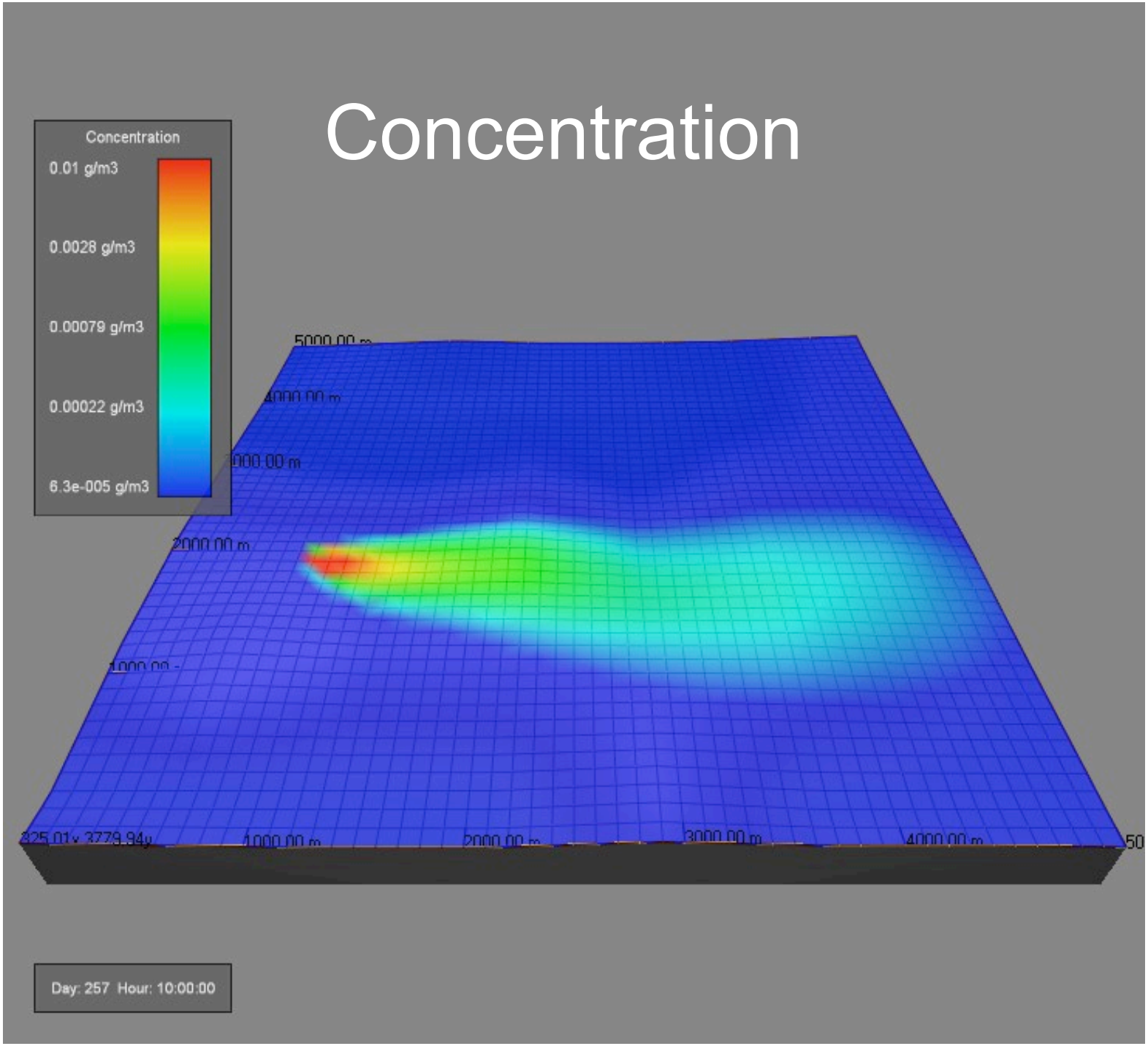
Predicting airflow & dispersion of pollutants around buildings


Region of Interest Editor
Region's Southwest Corner
South:
3779.9399
West:
325.0100
Region Size
Height:
5.0000
Width:
5.0000
Display
UTM Bounds
Degree Bounds
- Left click and drag edges to size grids.
- Shift drag to move entire grid.
- Left click and drag map to scroll.
- Right click and drag map to zoom.
Accept Region


A2C3d (FLOW and T&D Visualizer)
No Gradient Selected
5000.00 m
4000.00 m
3000.00 m
2000.00 m
1000.00
0.5250
0.3500
0.1750
0.0000
Land Use Color Key
Urban
Dryland Crop/Pasture
Irrigated Crop/Pasture
Mixed Dry/Irrigated
Crop/Dryland Mosaic
Crop/Wood Mosaic
Grassland
Shrub/Grass
Shrubland
Savanna
Forest Deciduous Broadleaf
Forest Deciduous Needle
Forest Evergreen Broadleaf
Forest Evergreen Needle
Forest Mixed
Water Bodies
Wetland Herbaceous
Wetland Wooded
Barren
Tundra Herbaceous
Tundra Wooded
Tundra Mixed
Tundra Bare Ground
Snow/Ice
Save Image
Save Movie
Print Image
Close
Day: 200
Hour: 20:00:00


Plume Age
2.00 Hours
1.50 Hours
1.00 Hours
0.50 Hours
0.00 Hours
2000.00 m
3000.00 m
4000.00 m
Day: 257 Hour: 10:00:00

Concentration



FLEXPART

FLEXPART is an atmospheric trajectory and particle dispersion model.

Applications of the model cover topics like nuclear accidents, pollution transport, greenhouse gas cycles, stratosphere-troposphere exchange, water cycle research, and others.

Developed by Andreas Stohl and others from:

Norwegian Institute of Air Research, Kjeller, Norway

Institute of Meteorology, University of Natural Resources and Applied Life Sciences, Vienna, Austria

Preparatory Commission for the Comprehensive Nuclear Test Ban Treaty Organization, Vienna, Austria

FLEXPART introduction

Lagrangian particle models compute trajectories of a large number of so-called particles (not necessarily representing real particles, but infinitesimally small air parcels) to describe the transport and diffusion of tracers in the atmosphere.

FLEXPART can be used forward in time to simulate the dispersion of tracers from their sources, or backward in time to determine potential source contributions for given receptors.

Available online at:

http://zardoz.nilu.no/~andreas/flextra+flexpart.html

System requirements & versions

FLEXPART, written in FORTRAN 77, is largely platform independent.

FLEXPART can be driven with meteorological input data from a variety of global and regional models, most commonly from the

- European Centre for Medium Range Weather Forecasts model (ECMWF)
- Global Forecast System model (GFS)
- The fifth generation NCAR/PSU mesoscale model (MM5)
- Weather Research and Forecasting model (WRF)

The ECMWF version of the model is considered the reference version. Version 8.1 is the most recent.

Files in directory options

Files for specifying the model run:

COMMAND

RELEASES

SPECIES

OUTGRID

The most important file is the COMMAND file which specifies (1) the simulation direction (either forward or backward), (2) the start and (3) the end time of the simulation, and (4) the frequency of the model output

Files in directory options

RELEASES defines:

- The beginning and the ending time of the particle release,
- Geographical coordinates of the lower left and upper right corners of the release location,
- type of vertical coordinate (above ground level, or above sea level),
- lower level and upper level of source box,
- the number of particles to be used

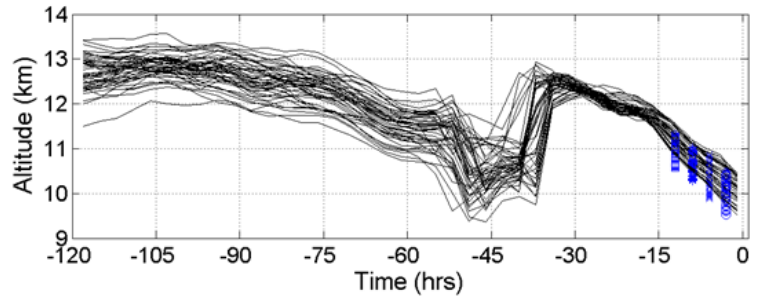
The particles are released from random locations within a four-dimensional box extending from the lower to the upper level above a rectangle (on a lat/lon grid) defined by the geographical coordinates, and between the release's start and end.

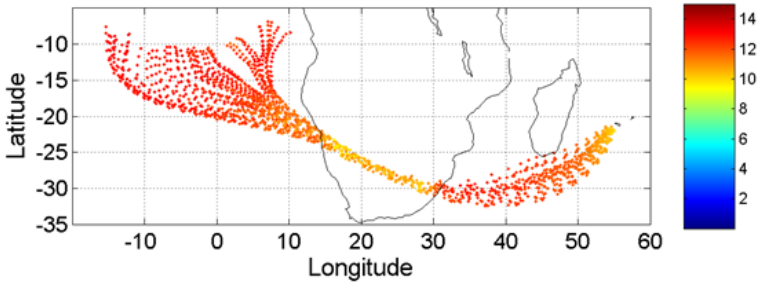
Files in directory options

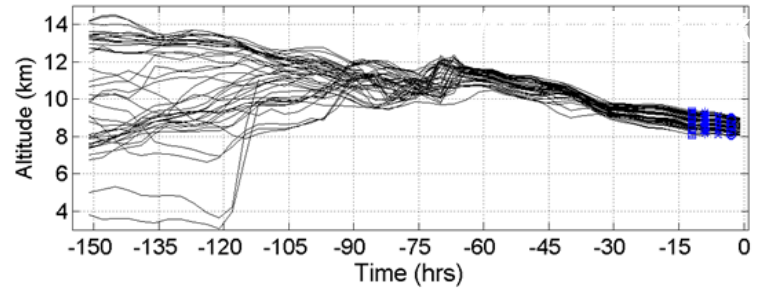
The SPECIES file is for providing initial emission information.

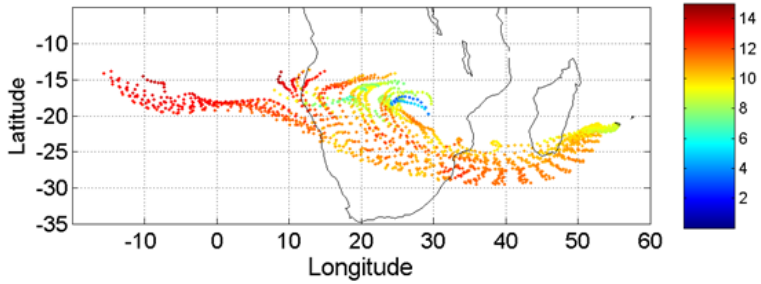
The file OUTGRID specifies the output grid.

Rather quick execution (< 10 minutes)

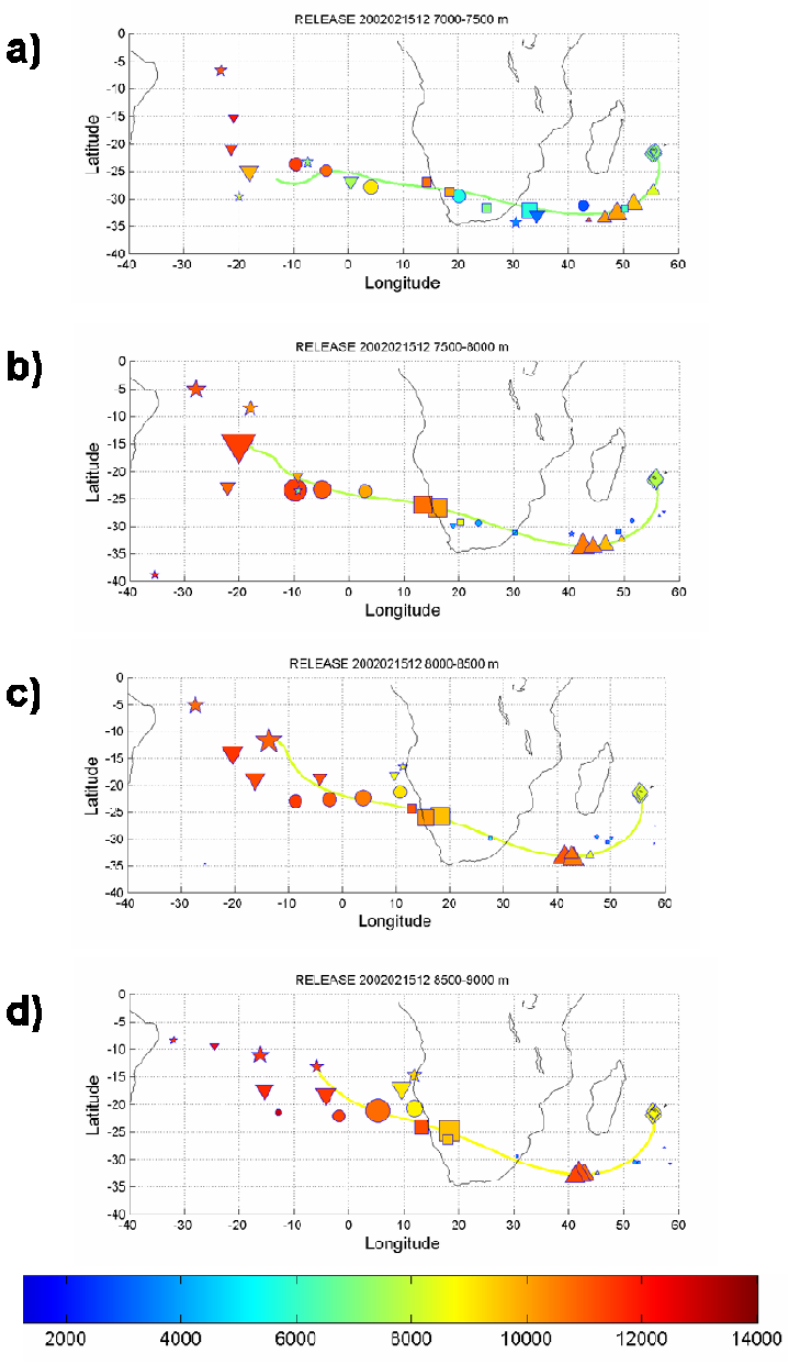


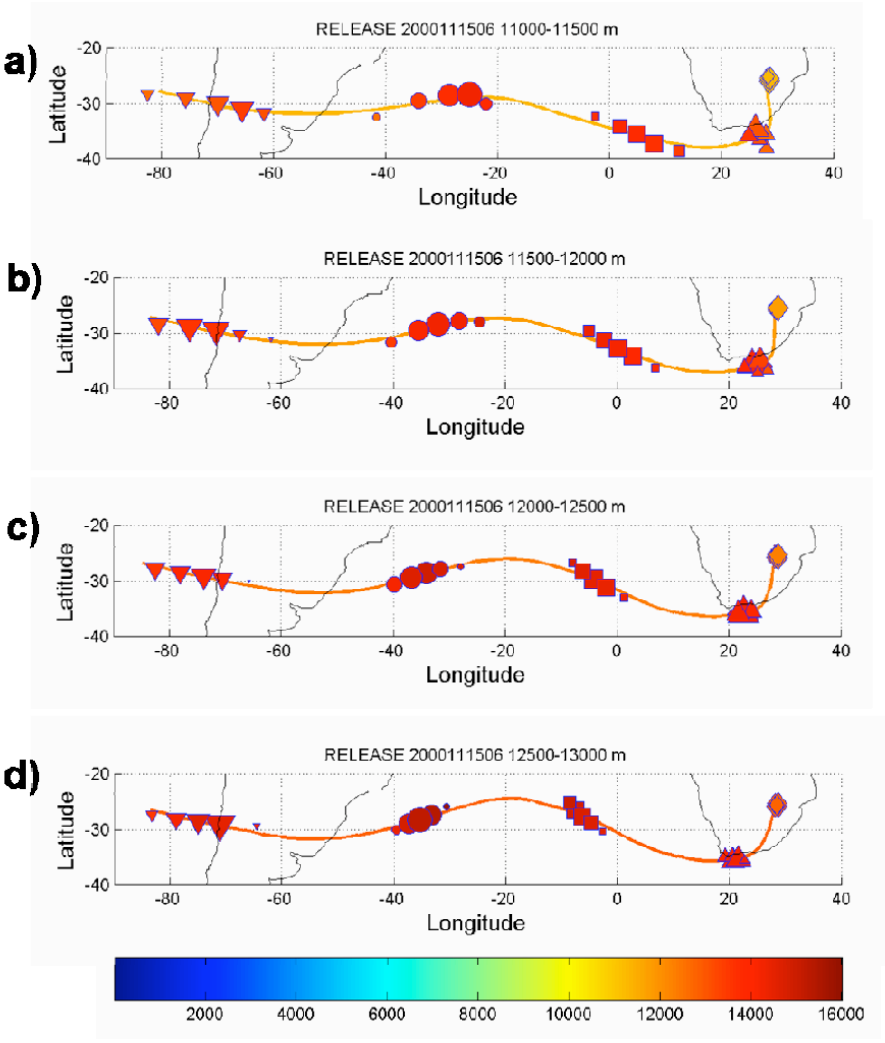




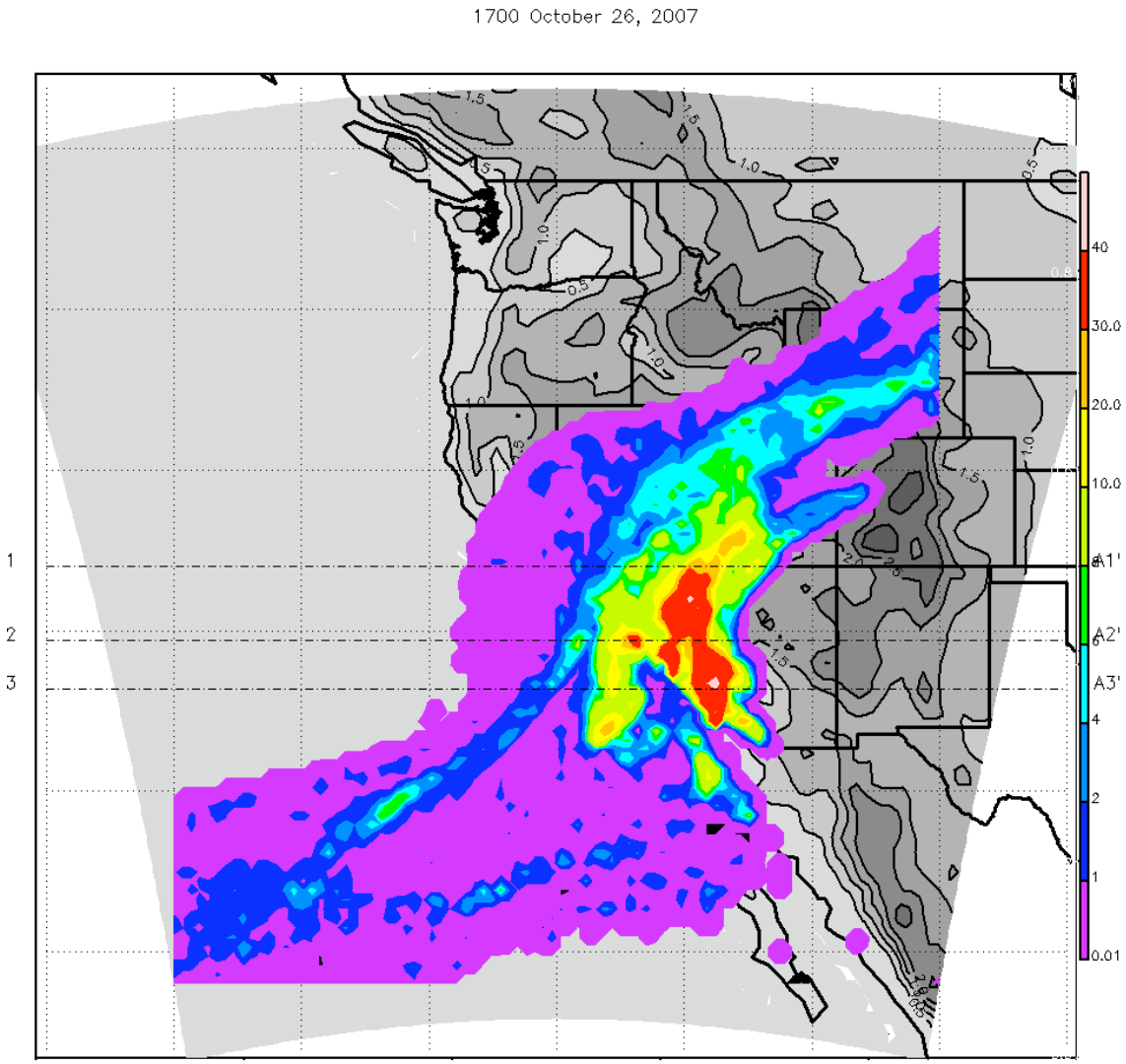


Not clustered plume trajectories



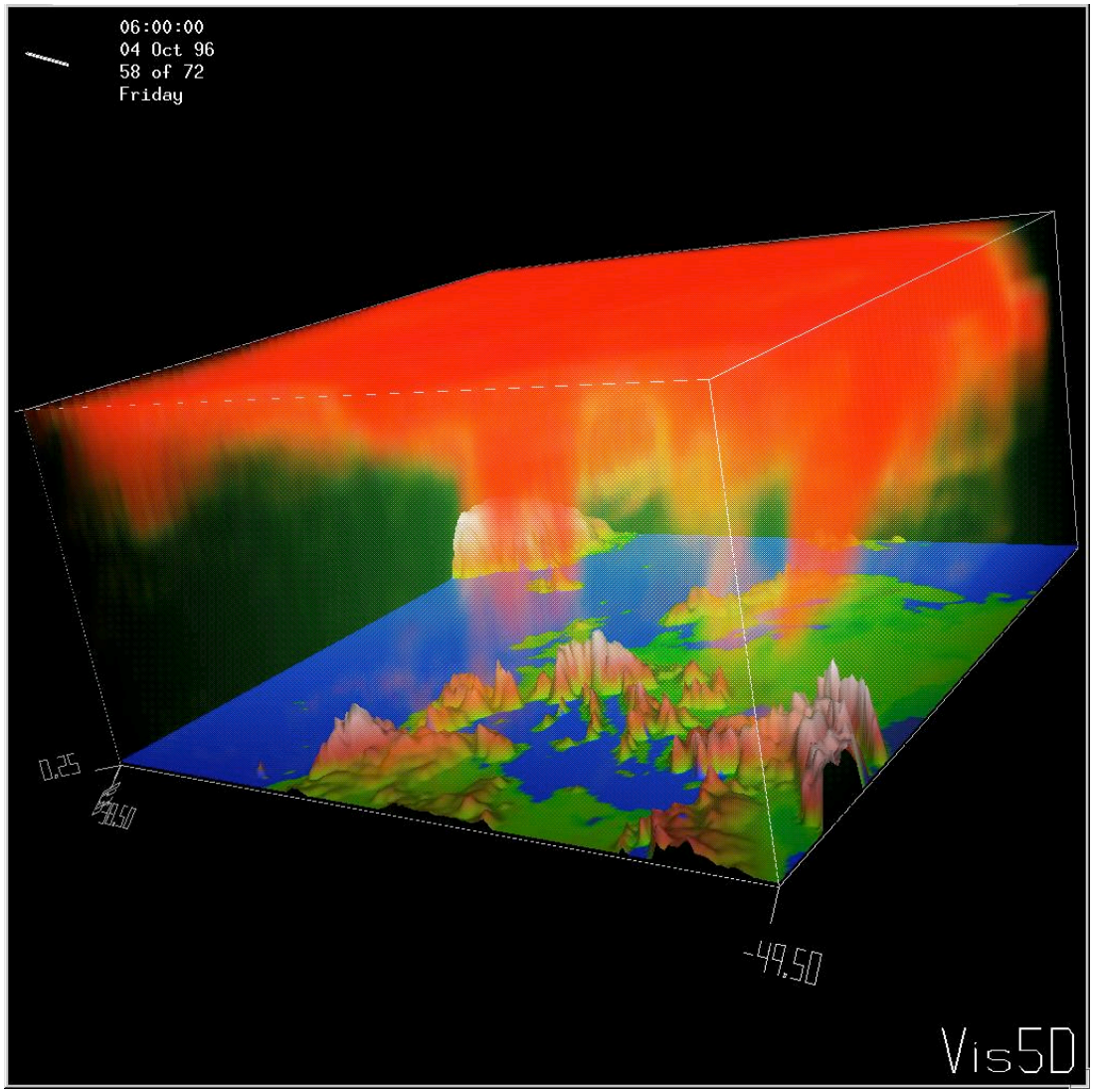


Clustered plume trajectories



Contour plot of concentration

FLEXPART used to model stratospheric intrusion into troposphere



FLEXPART Display

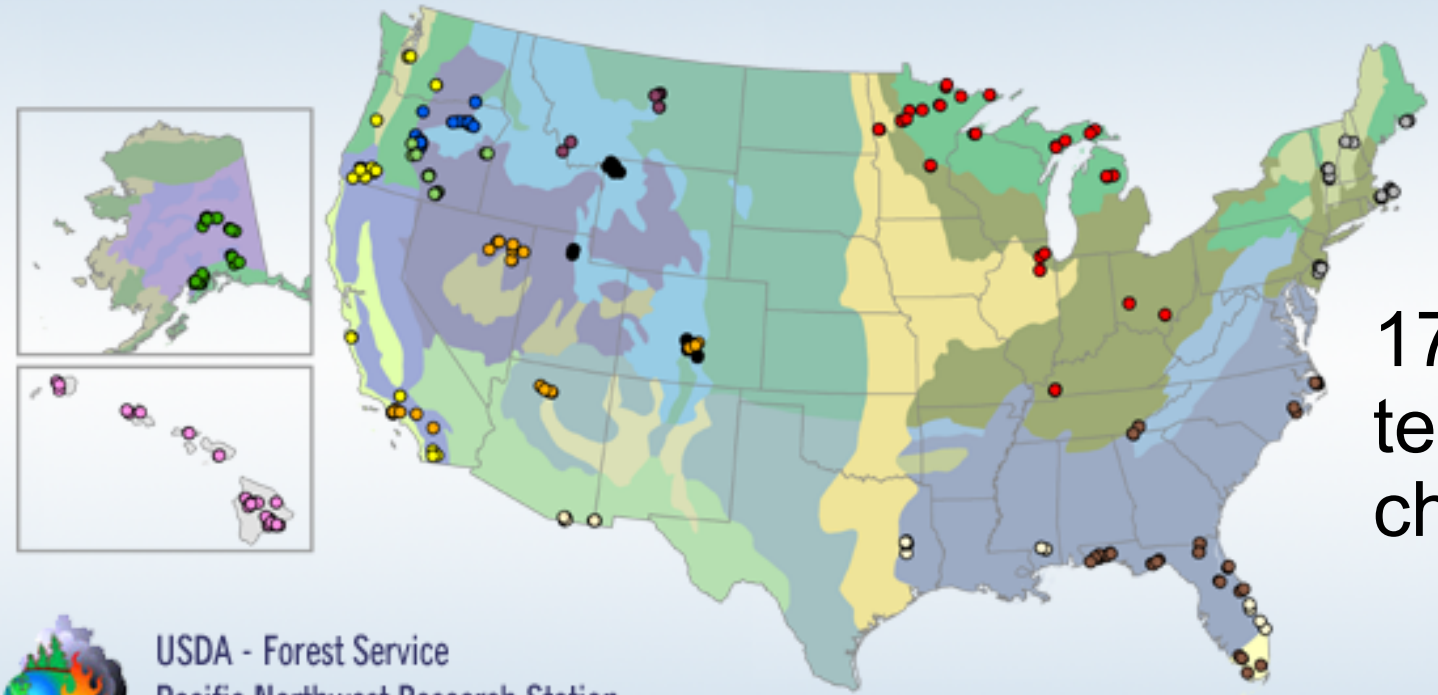
Display of FLEXPART output can be done using Vis5D, VAPOR, ParaView, IDL, or other independent software packages.

FEPS and other FERA software research tools.

FERA – Fire and Environmental Research Applications Team

- Natural Fuels Photo Series
- Fuel Characteristic Classification System (FCCS)
- Consume
- Fire Emission Production Simulator (FEPS)

Digital Photo Series



17 Pitch Pine templates to choose from

USDA - Forest Service
Pacific Northwest Research Station
FERA Pacific Wildland Fire Sciences Laboratory
Fire and Environmental Research Applications Team
400 N 34th Street, Suite 201 • Seattle, WA 98103 • 206.732.7800

Photo Series

- The Natural Fuels Photo Series provides an efficient tool to estimate fuel and stand characteristics for a variety of ecosystems throughout the United States.

- Information provided about tree canopy, species composition and size, understory height and coverage, woody fuels, and forest floor depth, constancy, and loading.


Longleaf pine with turkey oak component with
some palmetto shrub and wire grass cover.
The site has not been burned for 5 years.

Canopy characteristics
OVERALL:
Percent Cover 34%

OVERSTORY (> 4 inch dbh trees):
Density 65 stems/acre
Dbh 9.3 inches
Height 51.4 feet
Height to live crown 27.1 feet
Species composition 78% Pinus palustris
22% Quercus laevis

MIDSTORY (2-4" dbh saplings):
Density 65 stems/acre
Dbh 2.8 inches
Height 20.1 feet
Height to live crown 7.3 feet
Species composition 100% Quercus laevis

UNDERSTORY (0-2" dbh saplings):
Density 304 stem/acre
Dbh 1.1 inches
Height 9.6 feet
Height to live crown 6 feet
Species composition 93% Quercus laevis
7% Pinus palustris

Shrub characteristics
Percent cover 10%
Height 2.3 feet
Loading 1.21 tons/acre
Species composition 50% Serenoa repens
40% Vaccinium spp.
10% Ilex glabra

Nonwoody vegetation characteristics
Primary layer - grasses:
Percent cover 50%
Height 1.6 feet
Loading 1.34 tons/acre
Species composition 100% Aristida stricta

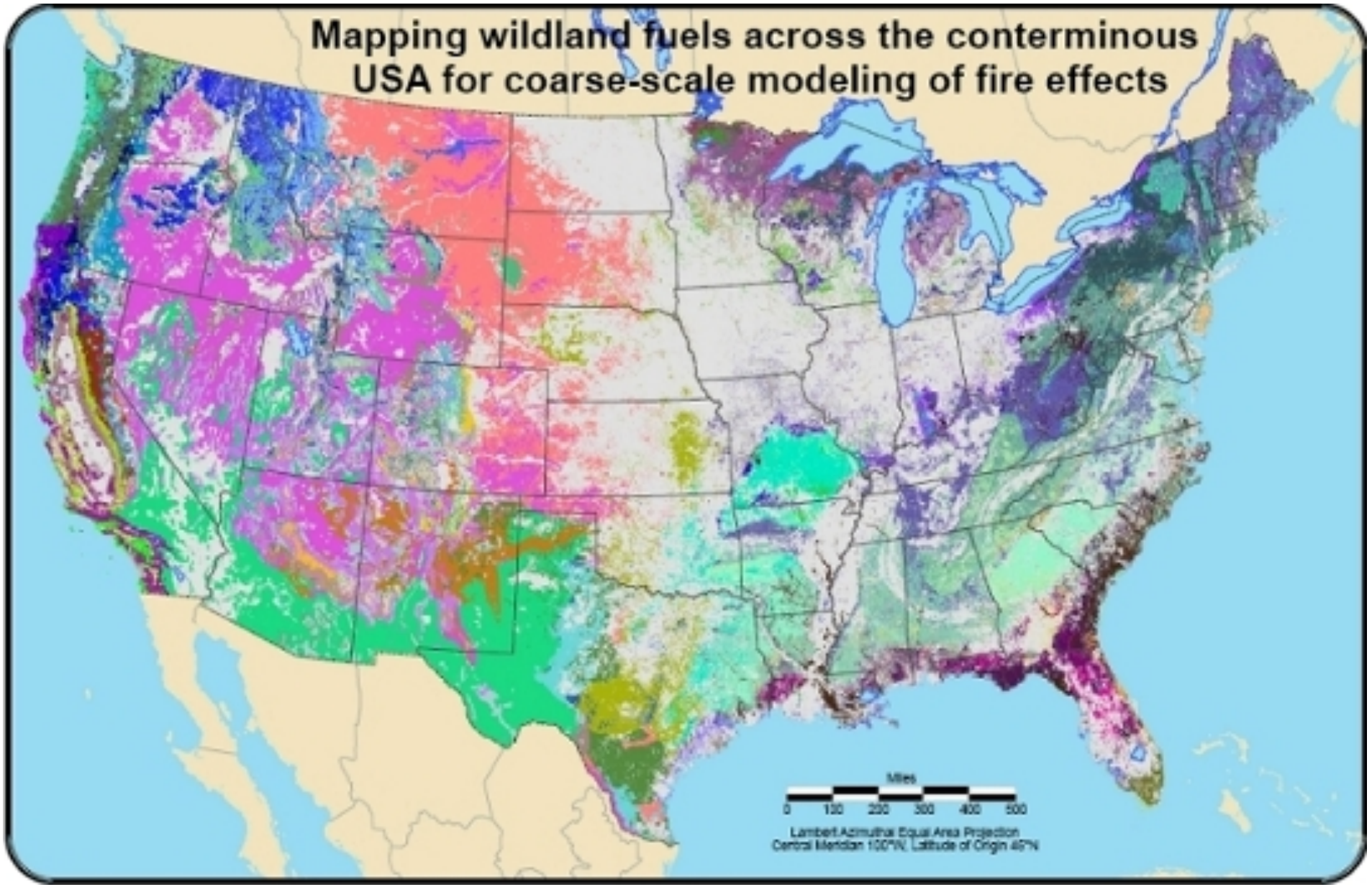
Woody fuel loadings
< 0.25 inch 0.2 tons/acre
0.25 to 1 inch 0.5 tons/acre
1 to 3 inches 0.3 tons/acre
3 to 9 inches 0.2 tons/acre
> 9 inches 0.0 tons/acre

Litter characteristics
Depth 1.1
% cover 80%
Type 50% broadleaf deciduous
50% long-needle pine


FCCS1.0 (1.71 200601091330)
FCCS
Fuel Characteristic Classification System
developed by the Fire and Environmental Research Applications Team
Seattle
SE Marshlands
FERA
USDA - Forest Service
Pacific Northwest Research Station
Pacific Wildland Fire Sciences Laboratory
Fire and Environmental Research Applications Team
400 N 34th Street, Suite 201 • Seattle, WA 98103
206.732.7800 • www.fs.fed.us/pnw/fera • pnw_fcshelp@fs.fed.us
Next . . .
Help

The FCCS:

- Allows designation of fuel properties and fire potentials across landscapes.
- Stores and classifies fuels data as fuelbeds (216 fuelbeds available).
- Enables users to create and store customized fuelbeds in the FCCS.
- Calculates physical characteristics of fuels based on fuelbed data.
- Calculates nine FCCS fire potentials based on the intrinsic properties of fuels.


Mapping wildland fuels across the conterminous USA for coarse-scale modeling of fire effects
Miles
0 100 200 300 400 500
Lambert Azimuthal Equal Area Projection
Central Meridian 100°W, Latitude of Origin 45°N

Six strata

- 1. **Canopy** - trees, snags, and ladder fuels.
- 2. **Shrub** - primary and secondary shrub layers.
- 3. **Nonwoody fuels** - primary and secondary nonwoody (i.e., grasses and other herbs) vegetation layers.
- 4. **Woody fuels** - all downed woody fuels, sound & rotten downed woody fuels, stumps, and woody fuel accumulations.
- 5. **Litter lichen moss** - litter, lichen, and moss layers.
- 6. **Ground fuels** - duff, squirrel middens, and basal accumulations.

For each fuelbed, the FCCS calculates:

- Surface fire behavior potential (0-9).
- Crown fire potential (0-9).
- Available fuel potential (0-9).

Welcome to Consume

Consume v3.0

developed by the Fire & Environmental Research Applications Team

Sagebrush
Northwestern Wyoming

USDA – Forest Service
Pacific Northwest Research Station
Pacific Wildland Fire Sciences Laboratory
FERA
Fire and Environmental Research Applications Team
400 N 34th Street, Suite 201 • Seattle, WA 98103
206.732.7800 • www.fs.fed.us/pnw/fera • consumehelp@fs.fed.us

Next Help

What is Consume?

- Consume is used to model the amount of fuel consumption and emissions of a prescribed or wildland fire.

- Consume accommodates a wide range of fuel characteristics, including those defined by the user.

Summary of Consumption Results

2/17/2010

Name		Area (acres)	Pre-burn Loading (tons/acre)	Consumption (tons)	Consumption (tons/acre)
Project	SouthernCaseStud	2,000	25.01	11,561.90	5.78
Unit	Unit 1	2,000	25.01	11,561.90	5.78
Fuelbed	Georgia Field Site	1,000	18.47	4,259.10	4.26
- Canopy			13.50	976.10	0.98
- Shrub			0.45	343.39	0.34
- Nonwoody			1.34	1,242.72	1.24
- Woody			1.20	802.85	0.80
- Piles			0.00	0.00	0.00
- Litter, Lichen & Moss			1.98	894.04	0.89
- Ground Fuels			0.00	0.00	0.00

Summary of Heat Release Results

2/17/2010

Name		Area (ft2)	Heat Release (btu)	(btu/ft2)
Project	SouthernCaseStudy	87,120,000	184,990,458,014	2,123.40
Unit	Unit 1	87,120,000	184,990,458,014	2,123.40
Fuelbed	Georgia Field Site	43,560,000	68,145,665,121	1,564.41
- Canopy			15,617,600,000	358.53
- Shrub			5,494,279,685	126.13
- Non woody			19,883,456,000	456.46
- Woody			12,845,657,436	294.90
- Litter, Lichen & Moss			14,304,672,000	328.39
- Ground Fuels			0	0.00

Summary Of Emissions

6/1/2006

Name	Pollutant	Area (acres)	Emissions (Tons)	Emissions (Tons/acre)
Fuelbed Georgia Field		1,000.0		
	PM		45.60	0.05
	PM_{10}		29.19	0.03
	$PM_{2.5}$		26.60	0.03
	CO		226.12	0.23
	CO_2		7,162.33	7.16
	CH_4		8.55	0.01
	NMHC		8.79	0.01

Fire Emission Production Simulator

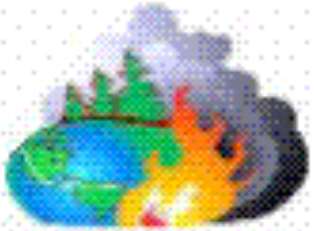
Version 1.1.0

Developed By:

David V. Sandberg, USDA Forest Service,
Pacific Northwest Research Station

Gary K. Anderson, HCG inc.

Robert A. Norheim, University of Washington



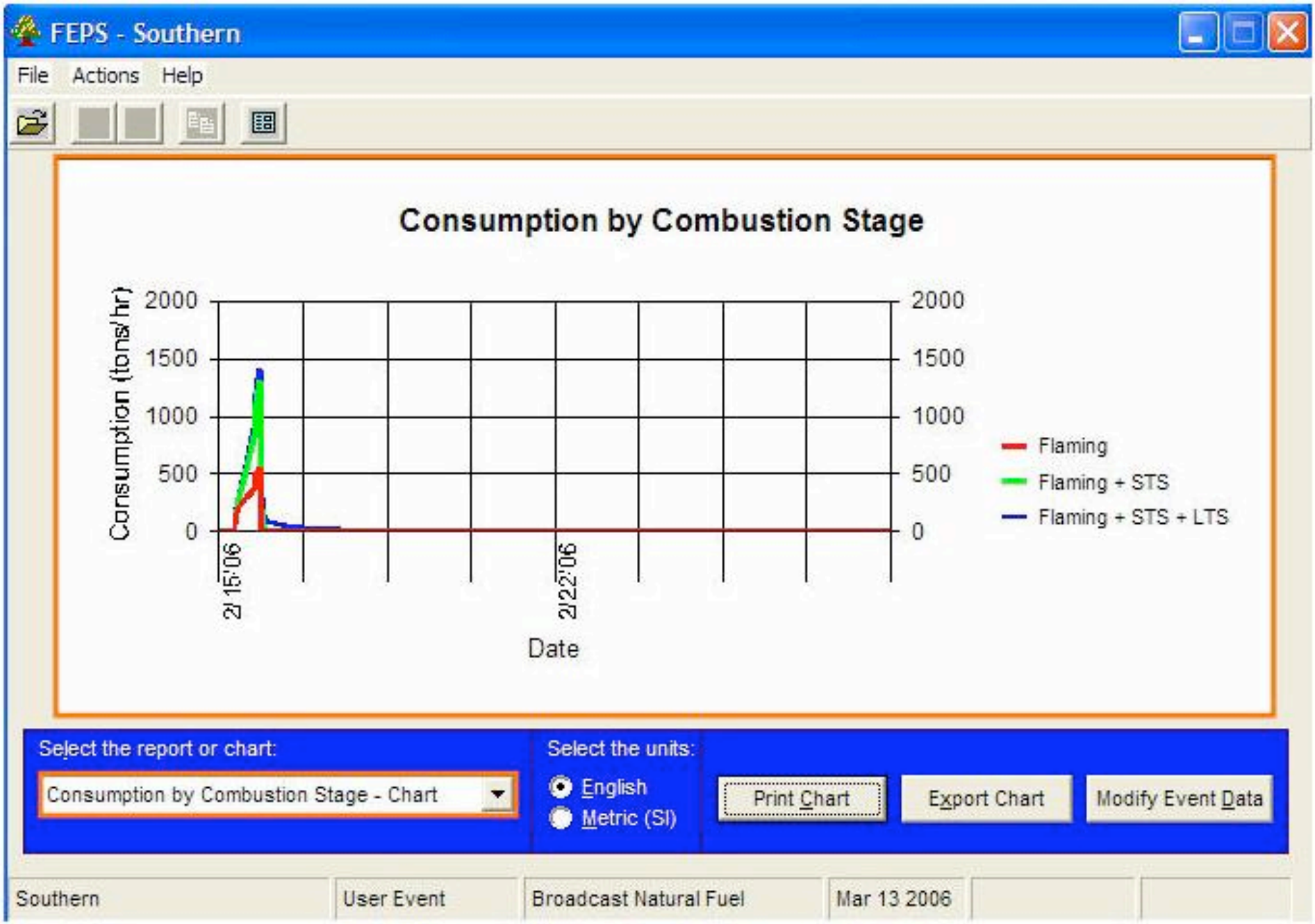
FERA
Fire and Environmental
Research Applications

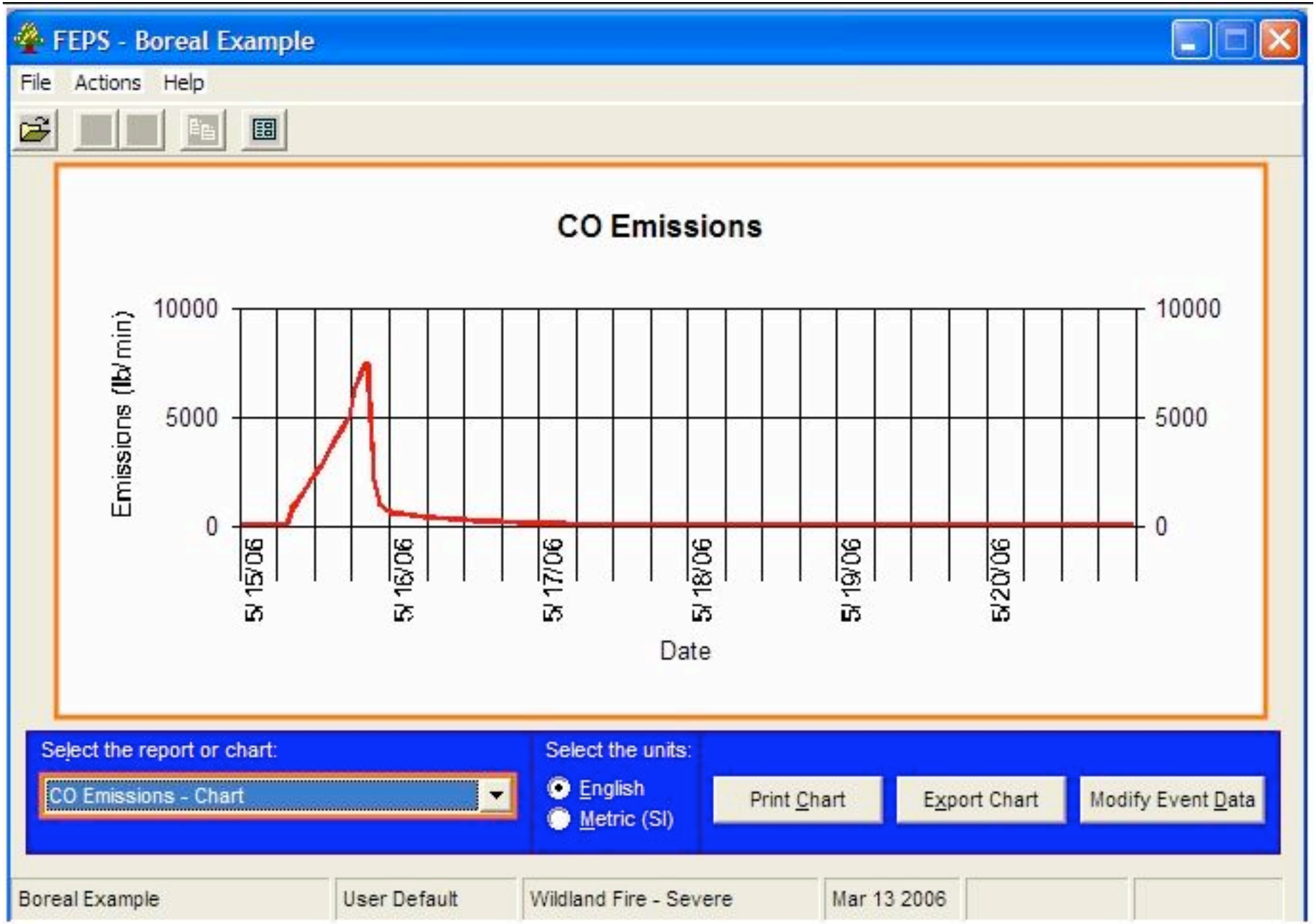
What is FEPS?

- FEPS predicts fuel consumption, emissions and heat release characteristics of prescribed burns and wildland fires. Total burn consumption is distributed over the life of the burn to generate hourly emission and release information.

Information needed for FEPS

- **Event Information**: records basic information about the event including event name, date, area, fire shape, type of burn and general descriptive information.
- **Fuel Loading**: up to 5 fuel profiles that represent fuel loadings for a unique area within the burn.
- **Fuel Moisture**: up to 6 fuel moisture profiles and automatically calculates percentage of fuels consumed from each fuel profile based on a specified fuel moisture profile.
- **Consumption**: reports total fuel consumption and fuel consumption in the flaming, short-term smoldering and long-term smoldering stages of combustion.
- **Hourly Input Data**: Allows users to specify how much of the fire event was in a given fuel profile and hourly weather information.


FEPS - Southern
File
Actions
Help
Consumption by Combustion Stage
Consumption (tons/hr)
2000
1500
1000
500
0
2/15/06
2/22/06
Date
Flaming
Flaming + STS
Flaming + STS + LTS
Select the report or chart:
Consumption by Combustion Stage - Chart
Select the units:
English
Metric (SI)
Print Chart
Export Chart
Modify Event Data
Southern
User Event
Broadcast Natural Fuel
Mar 13 2006


FEPS - Boreal Example
File
Actions
Help
CO Emissions
Emissions (lb/min)
10000
5000
0
5/15/06
5/16/06
5/17/06
5/18/06
5/19/06
5/20/06
Date
Select the report or chart:
CO Emissions - Chart
Select the units:
English
Metric (SI)
Print Chart
Export Chart
Modify Event Data
Boreal Example
User Default
Wildland Fire - Severe
Mar 13 2006

Future directions

Develop a canopy layer model for WRF

Develop an ARPS version of FLEXPART

Create 3D displays of FLEXPART results from both WRF and ARPS

Use WRF, ARPS, and FLEXPART to model case studies.