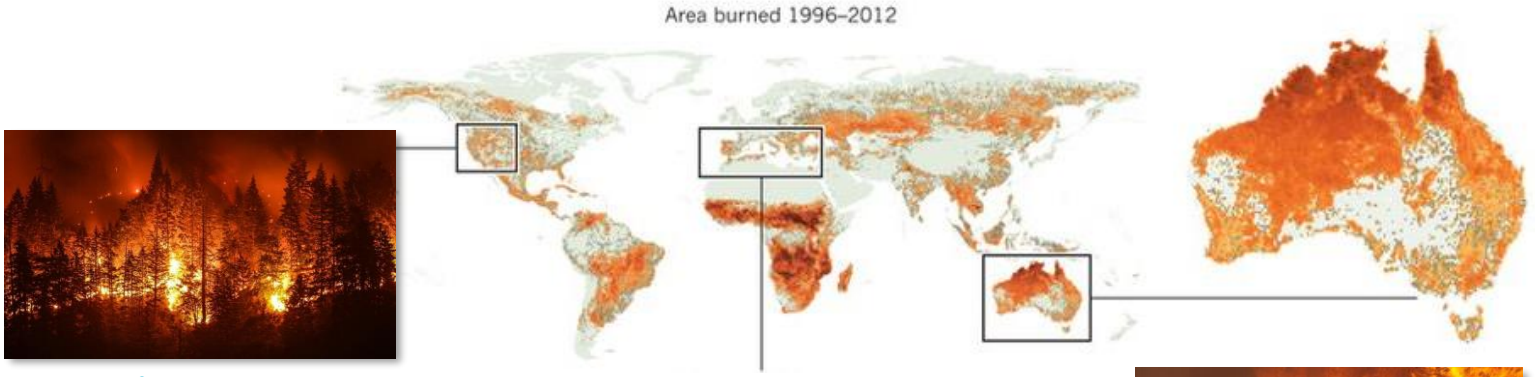
Spark

Feb 2025

Introduction

Wildfires are a devastating worldwide hazard



California 2018

Greece 2018

Australia 2009

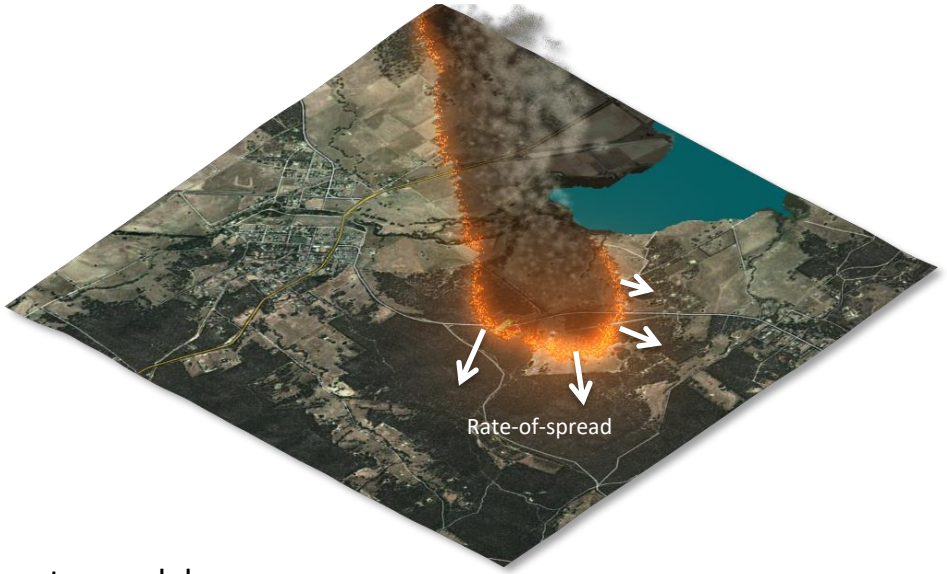
Source: Moritz et al. Nature 515, 58–66. *The cumulative area burned between 1996 and 2012 in millions of hectares (Mha) per mapped cell.*

Introduction

Need to simulate wildfires for risk modelling and operational management

Given:

- Ignition conditions (points, lines or areas)
- Information on the fuel and landscape
- Weather data
- Firebreaks and suppression



We need:

- Where the fire will go
- The intensity of the fire
- Heat flux on structures
- Where firebrands will land
- …

All of these elements must be included in a computer model
Computer model must be rapid enough for operational prediction

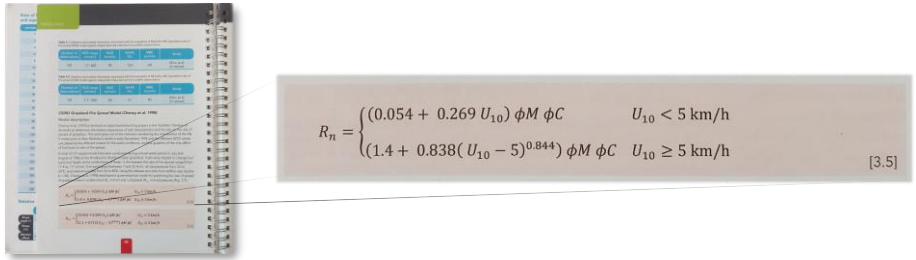
Introduction

The rate-of-spread depends on:

- The type of fuel
- The condition of the fuel (amount, moisture level, …)

Empirical rate of spread models developed from experiments

- Mathematical function for rate-of-spread

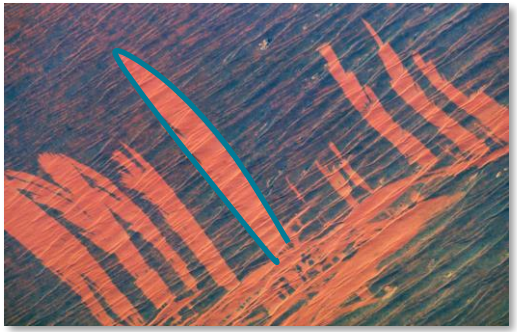


$$R_n = \begin{cases} (0.054 + 0.269\,U_{10})\,\phi M\,\phi C & U_{10} < 5\ \text{km/h} \\ (1.4 + 0.838(U_{10} - 5)^{0.844})\,\phi M\,\phi C & U_{10} \geq 5\ \text{km/h} \end{cases} \quad [3.5]$$

Need to use many different models for fire prediction

- Each model may require different data

Eucalypt fire. Source: RMIT



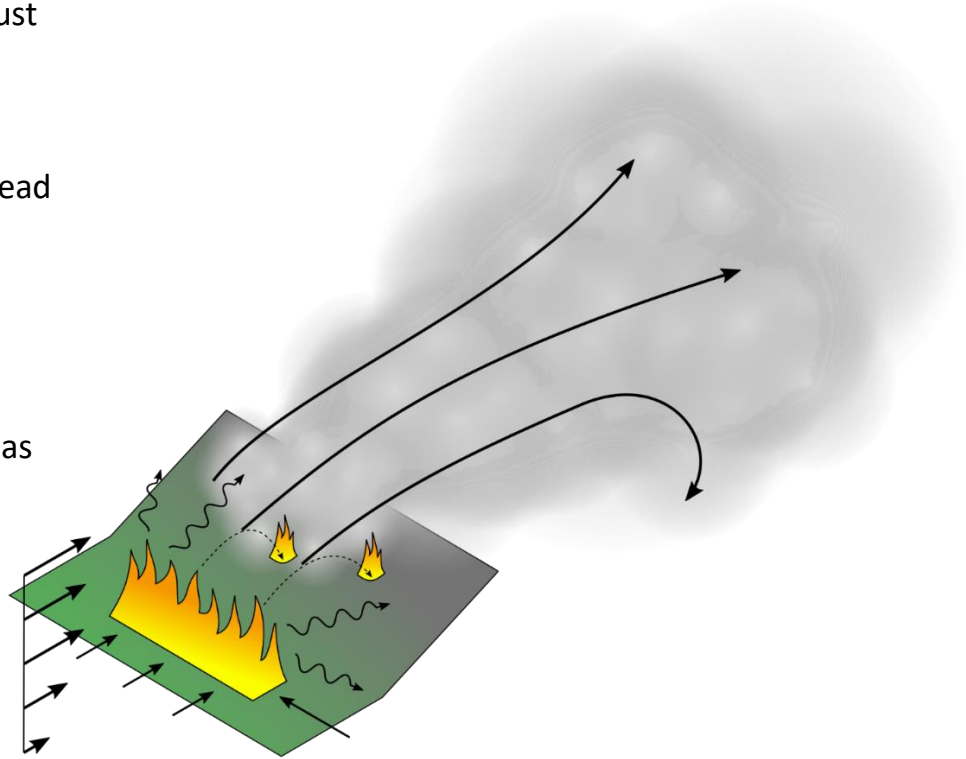
Spinifex fire. Source: NASA Earth Observatory

Introduction

In addition to the rate of spread the following must also be considered:

- Terrain - fires move faster uphill
- Local wind effects - channelling and lateral spread
- Smoke - long range effect
- ‘Near-field’ - fire interacts with itself
- Radiation - cause structure damage
- Firebrands - create unpredictable new fires

Ongoing worldwide research into all of these areas



Spark

Spark is a wildfire prediction *framework*:

- Based on configurable scripts wherever possible
- Rate-of-spread based on input data – wind, fuel, terrain
- Compatibility with all common geospatial data types
- Plug-ins for firebrands, radiant heat flux, terrain, fire feedback
- Python-based for further customisation
- Web front end (SparkWeb) and server (Spark server)

Modelling

Computational wildfire models:

Front tracking

Cellular

Front tracking

- Represents perimeter as line
- Very efficient to update node positions
- Need to filter nearby points
- Lines can get tangled after update/merging

Cellular methods

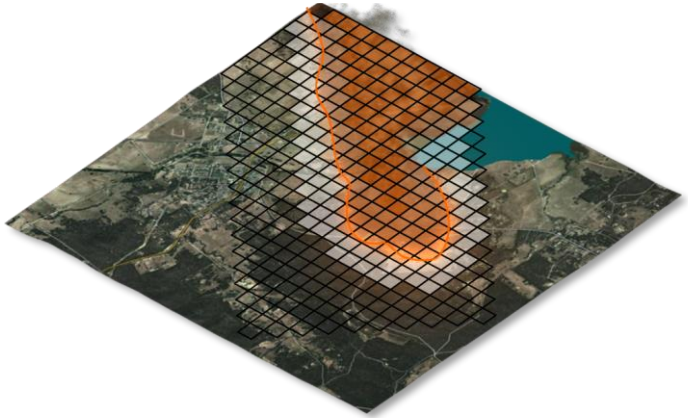
- Domain is a set of cells
- Fire spreads from cell to cell
- Extremely efficient processing
- Cell geometry affects simulation

Modelling

Spark model

Level set method:

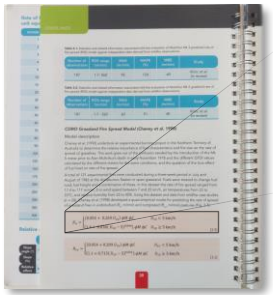
- Precise control of rate-of-spread in each cell
- Automatically handles merging fires
- Efficient and scalable on new computer hardware



Level set method

Models:

- Defined using scripts, not hard-coded
- Inputs and output layers can be referenced and used
- All projections, spatial and temporal sampling transparently handled



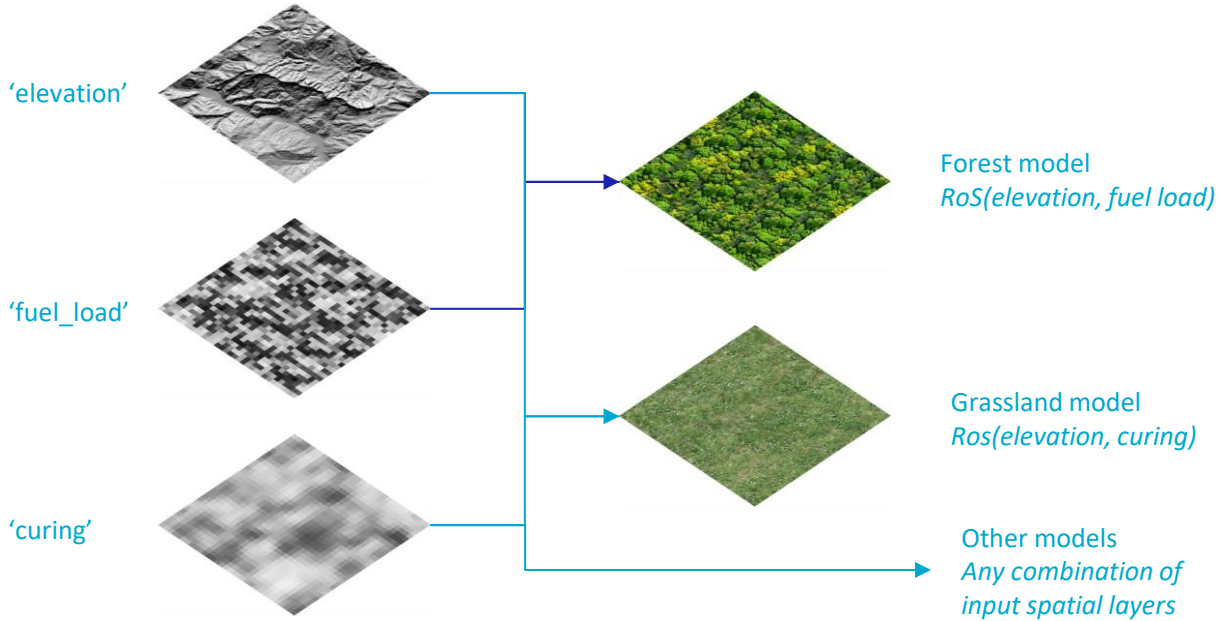
```
// Calculate spread rate from Cheney et al. (1998) (need to convert spread rate to m/s from km/hr)
if ( wind >= 5.0 )
    speed = ( 1.4 + 0.838 * pow( (wind - 5), 0.844 ) ) * moisture_coeff * curing_coeff / 3.6;
else
    speed = (0.054 + 0.269 * wind) * moisture_coeff * curing_coeff / 3.6;
```

Example script for grassland fires in Spark

Data

Any user-defined variables, layers or series can be used

- System handles spatial and temporal sampling
- Integration to support any geospatial data type

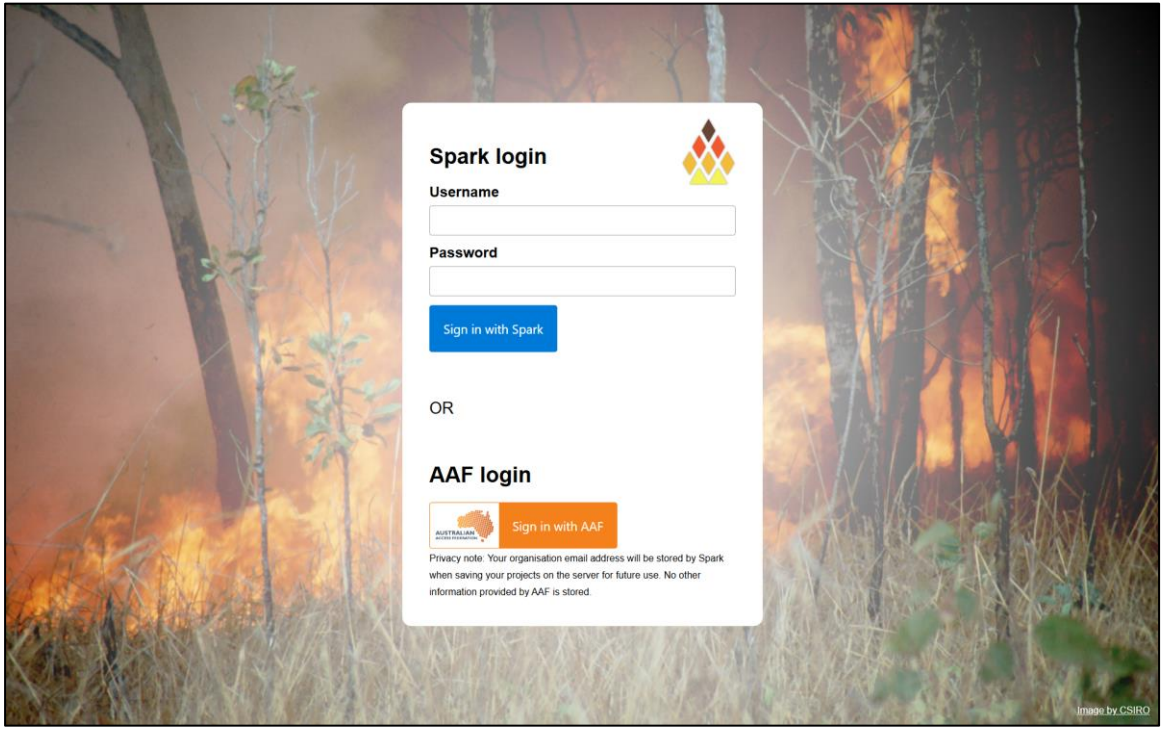


SparkWeb

SparkWeb

Usage

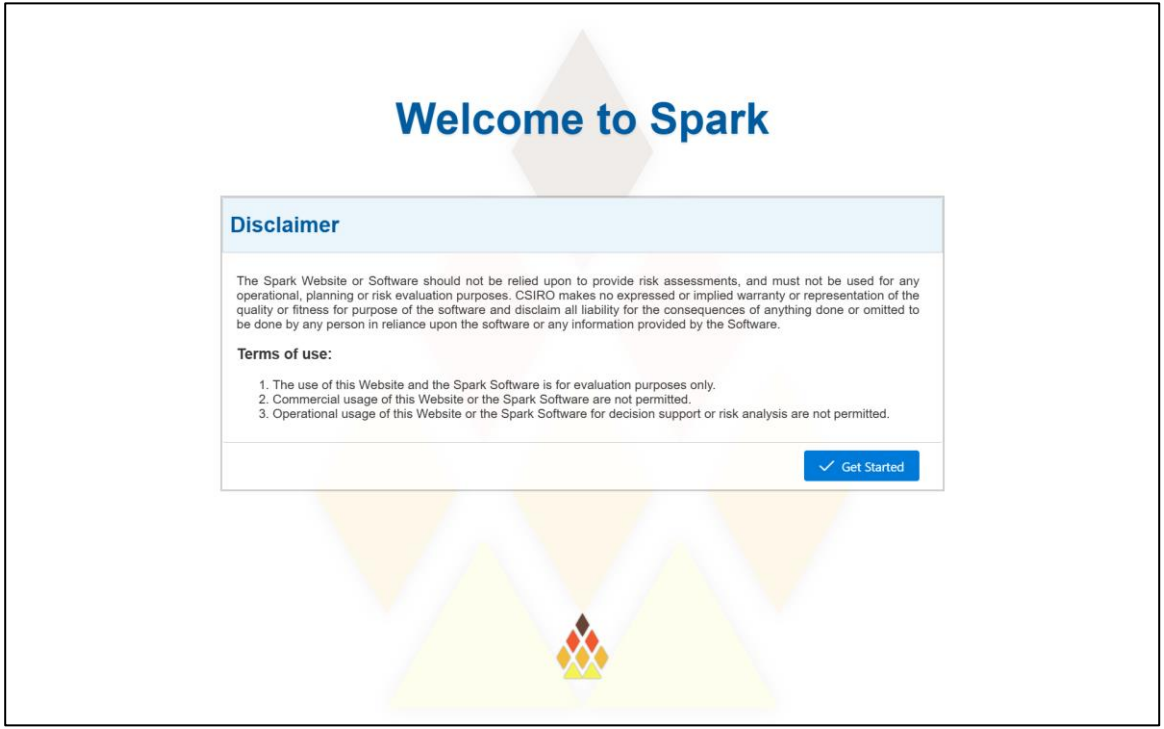
- Authentication required



SparkWeb

Usage

- Authentication required
- Terms of use



SparkWeb

Usage

- Authentication required
- Terms of use
- Create a new project

SparkWeb

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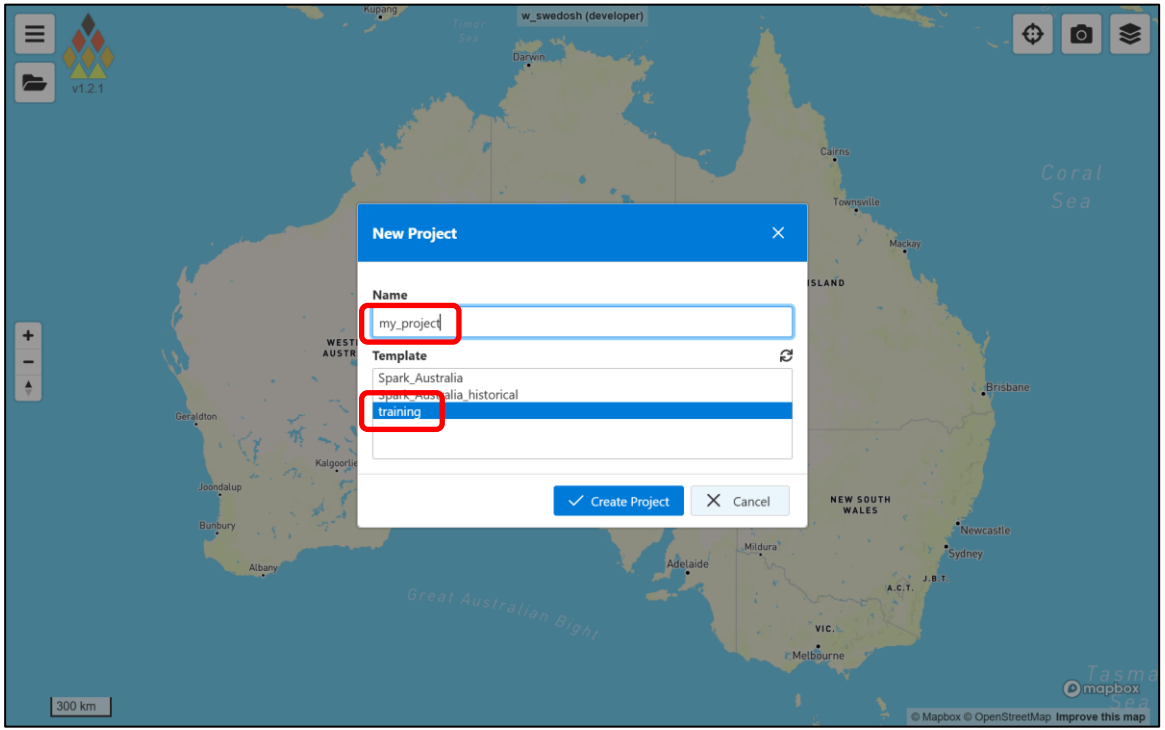
Usage

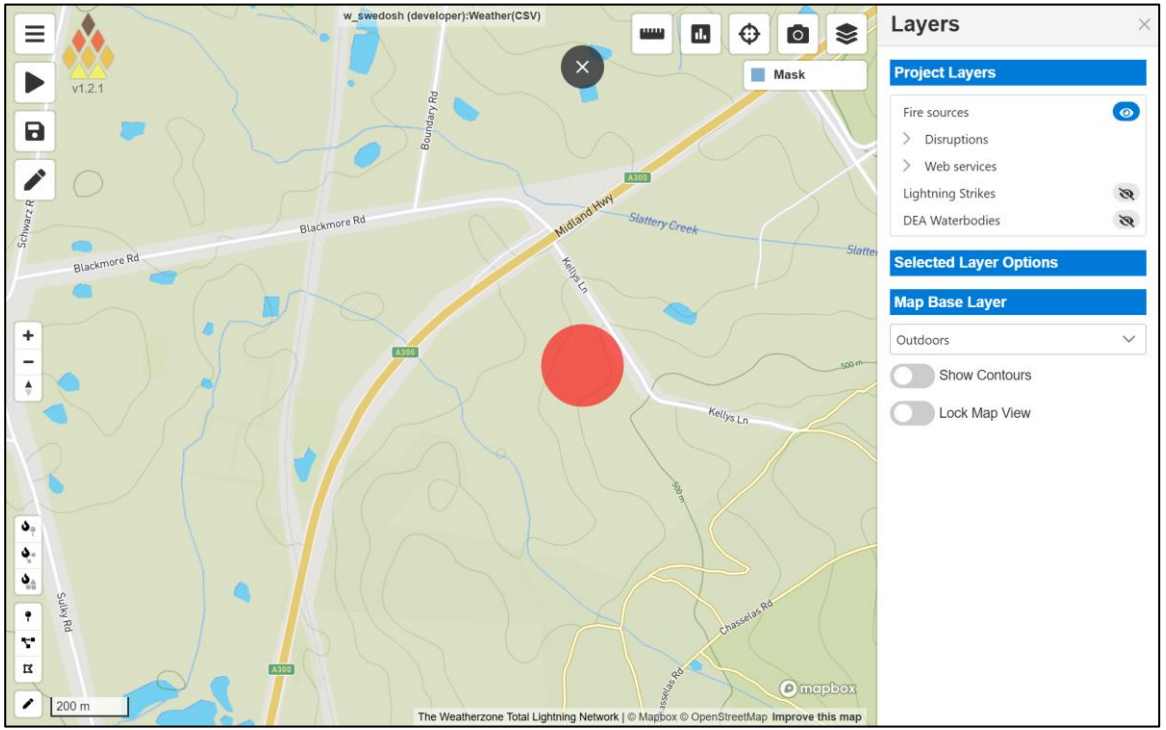
- Authentication required
- Terms of use
- Create a new project
  - *Projects must be named*
  - *Pre-populated templates*



SparkWeb

Usage

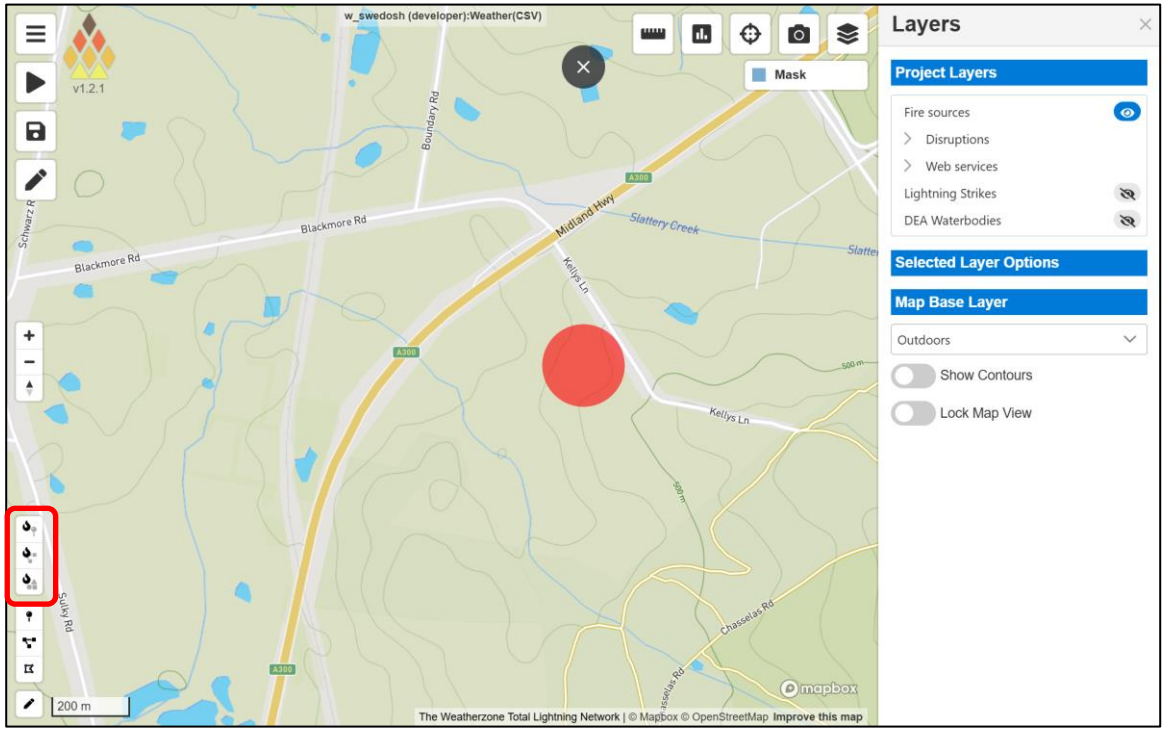
- Authentication required
- Terms of use
- Create a new project
  - *Projects must be named*
  - *Pre-populated templates*
- Layer panel on right-hand side



SparkWeb

Usage

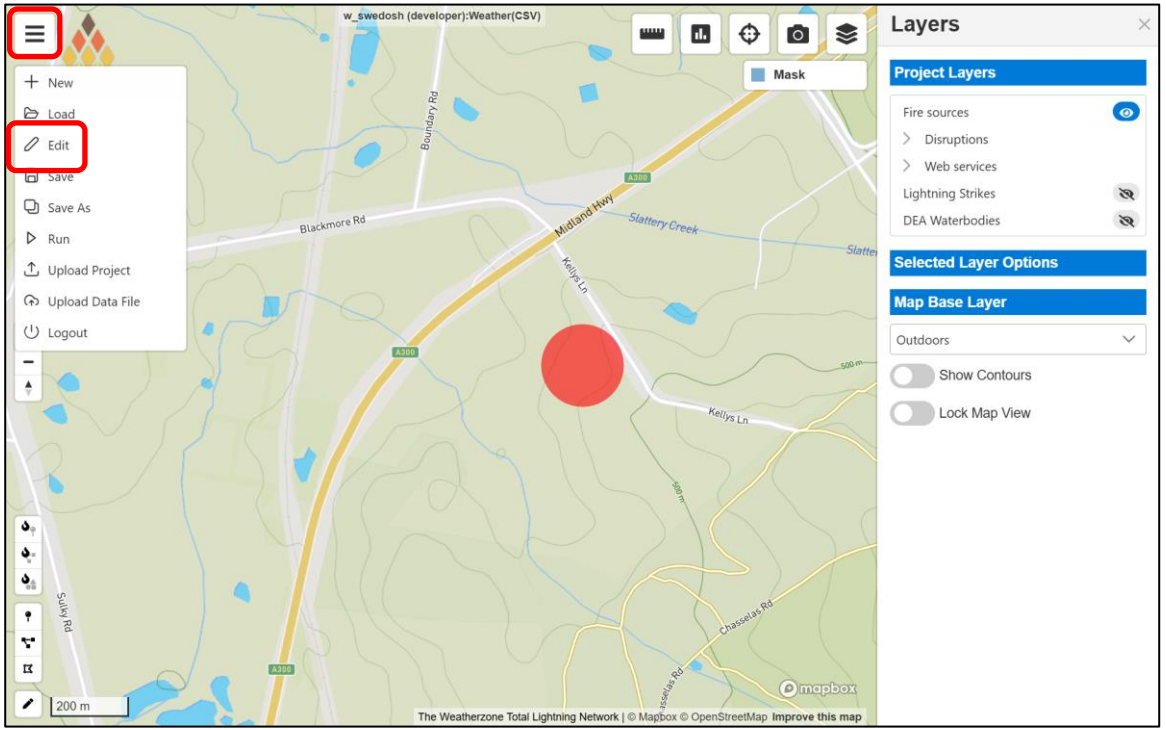
- Authentication required
- Terms of use
- Create a new project
  - *Projects must be named*
  - *Pre-populated templates*
- Layer panel on right-hand side
- Fire input conditions
  - *Tools on lower left*
  - *Point, line or polygon tool (top to bottom)*



SparkWeb

Usage

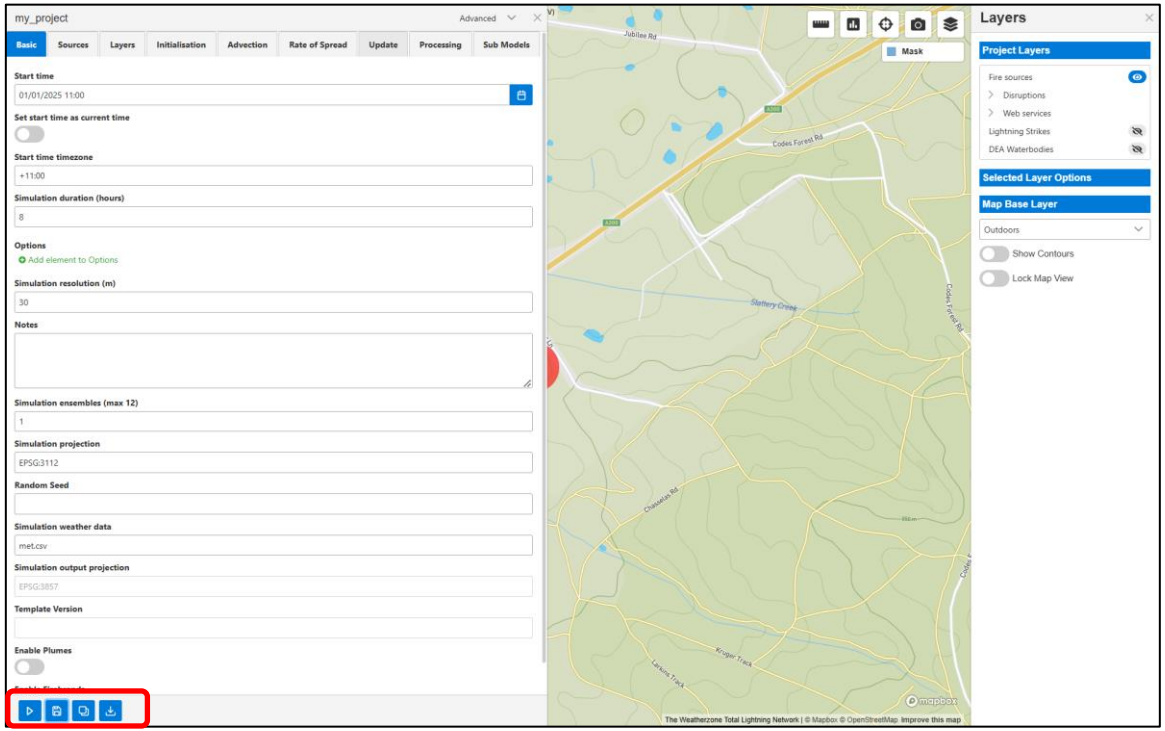
- Authentication required
- Terms of use
- Create a new project
  - *Projects must be named*
  - *Pre-populated templates*
- Layer panel on right-hand side
- Fire input conditions
  - *Tools on lower left*
- Basic simulation parameters, accessed via menu then edit (or edit pencil icon on main screen)



SparkWeb

Usage

- Authentication required
- Terms of use
- Create a new project
  - *Projects must be named*
  - *Pre-populated templates*
- Layer panel on right-hand side
- Fire input conditions
  - *Tools on lower left*
- Basic simulation parameters
  - *Start date and time*
  - *Time zone*
  - *Simulation duration*
  - *Simulation resolution*
- Project controls
  - *Run*
  - *Save*
  - *Save as*
  - *Download*



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- Create a new project
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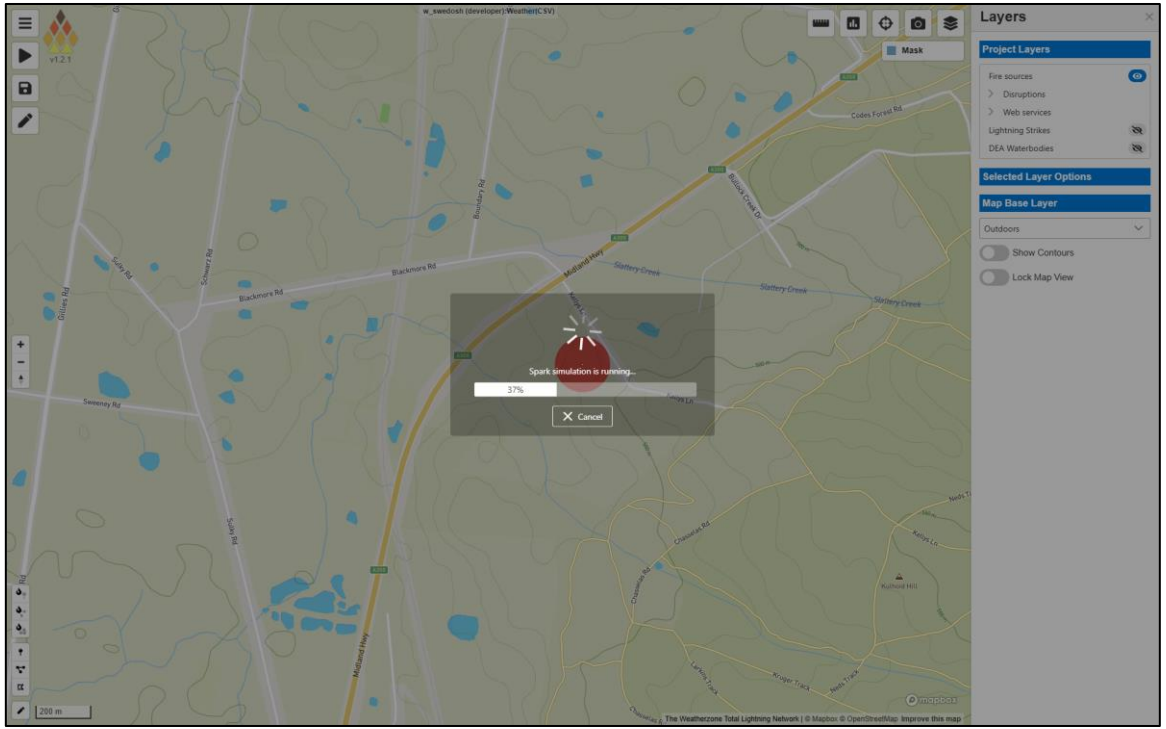
- Fire input conditions
  - *Tools on lower left*
- Basic simulation parameters
  - *Start date and time*
  - *Time zone*
  - *Simulation duration*
  - *Simulation resolution*
- Project controls
- Progress
  - *Shows when you press 'Run'*
  - *Any errors reported at this stage*



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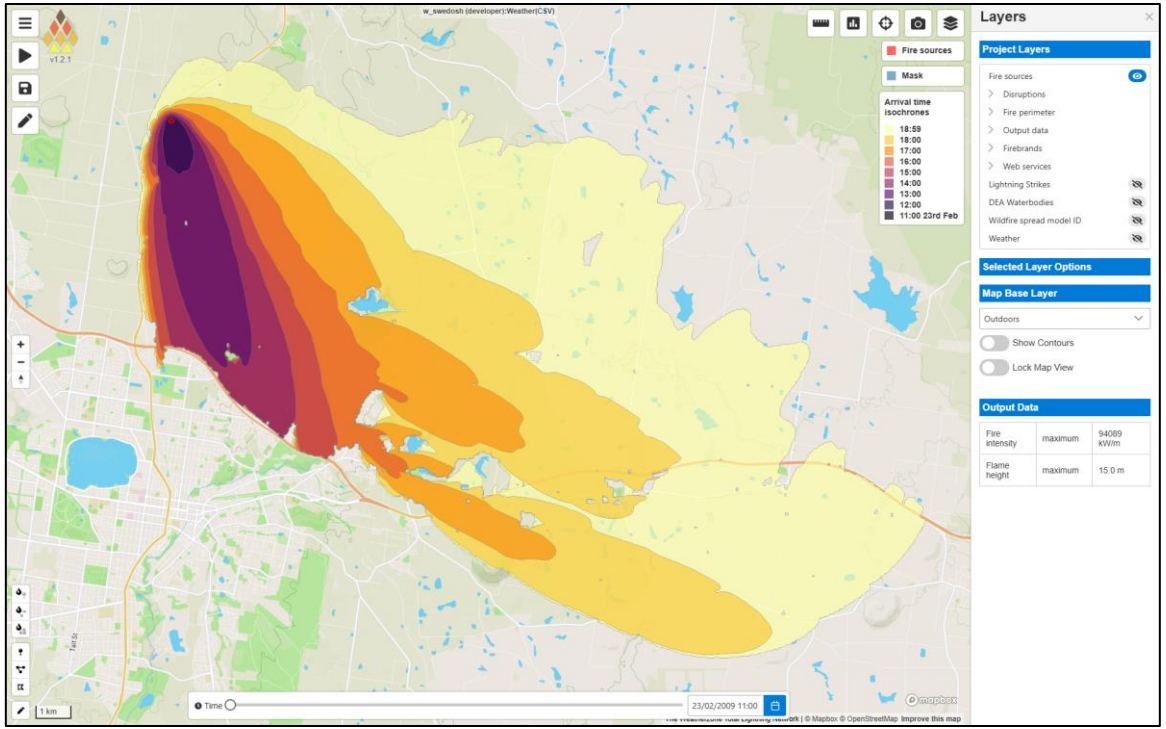
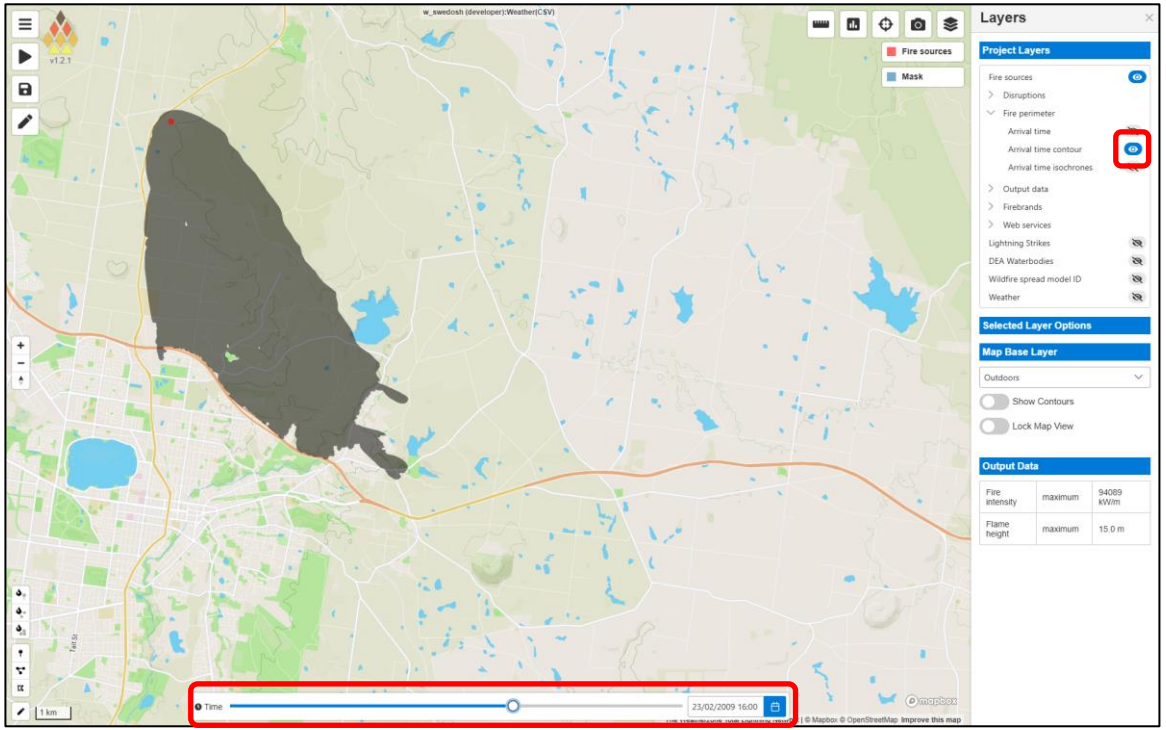
- Create a new project
  - *Projects must be named*
  - *Pre-populated templates*
- Layer panel on right-hand side
- Fire input conditions
  - *Tools on lower left*
- Basic simulation parameters
  - *Start date and time*
  - *Time zone*
  - *Simulation duration*
  - *Simulation resolution*
- Project controls
- Progress
  - *Shows when you press 'Run'*
  - *Any errors reported at this stage*
- Output of fire simulation
  - *Colours represent hourly progress*



SparkWeb

Results and visualisation

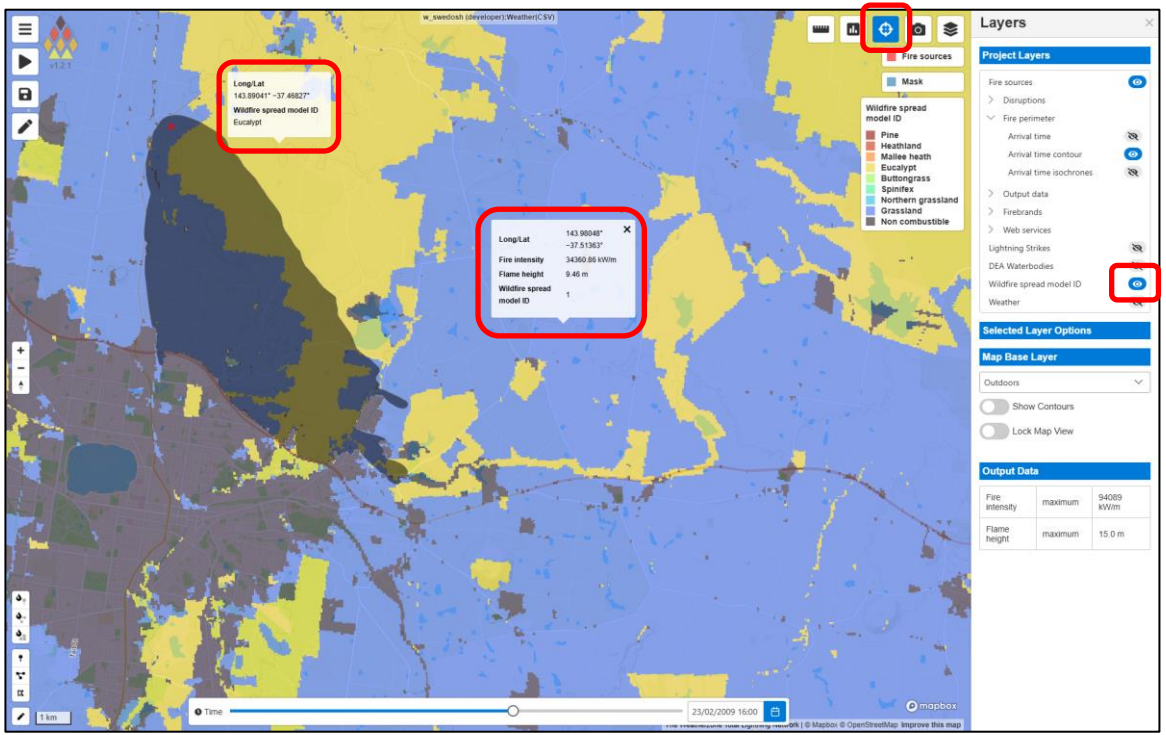
- Layers
  - *List on right-hand side*
  - *Visibility controlled by view icons*
- Shaded fire contour
  - *Dynamic outline based on time slider*



SparkWeb

Results and visualisation

- Layers
  - *List on right-hand side*
  - *Visibility controlled by view icons*
- Shaded fire contour
  - *Dynamic outline based on time slider*
- Wildfire model layer
  - *Cell evaluation using inspection tool*
  - *Current value of all visible layers under mouse*
  - *Left click for all layer values (shows fireline intensity etc.)*



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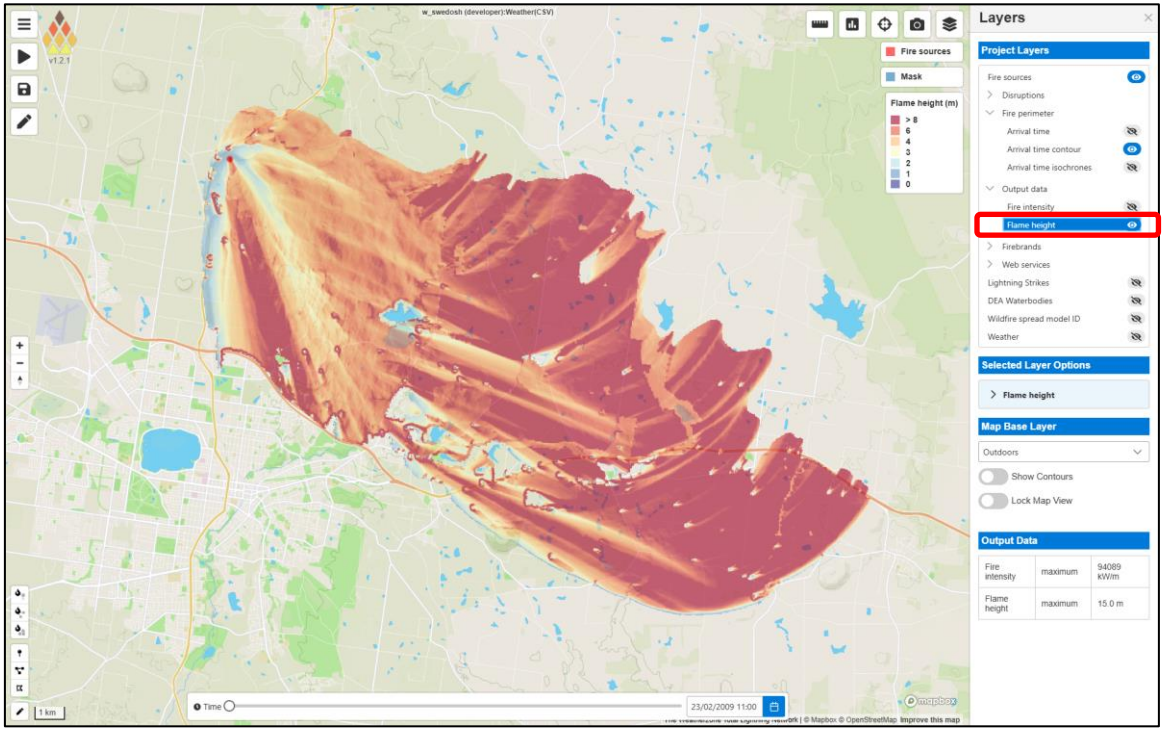
  - *Cell evaluation using inspection tool*
  - *Current value of all visible layers under mouse*
- Flame height layer
  - *Fireline intensity also available*



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Results and visualisation

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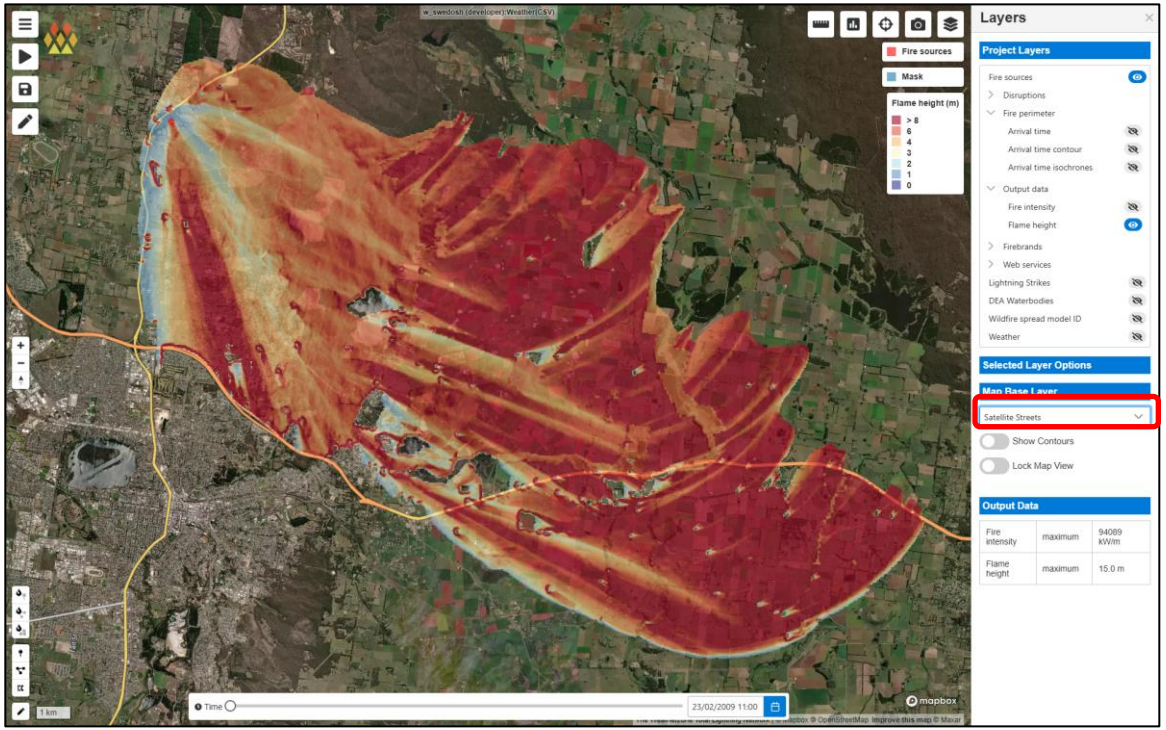
  - *Dynamic outline based on time slider*
- Wildfire model layer
  - *Cell evaluation using inspection tool*
  - *Current value of all layers under mouse*
- Flame height layer
- Base map
  - *Various base map options*



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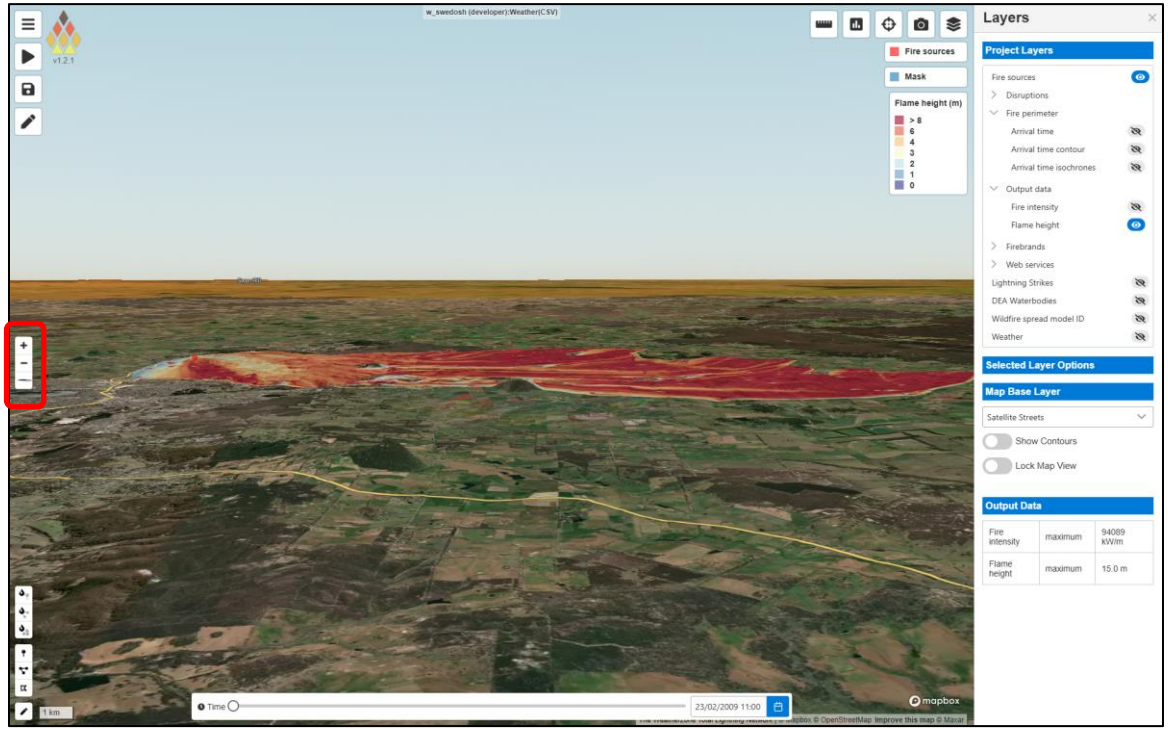
  - *Current value of all layers under mouse*
- Flame height layer
- Base map
  - *Various base map options*
- 3D view
  - *Right mouse or ctrl+left mouse to rotate view*
  - *Mousewheel to zoom*
  - *View reset using compass button*



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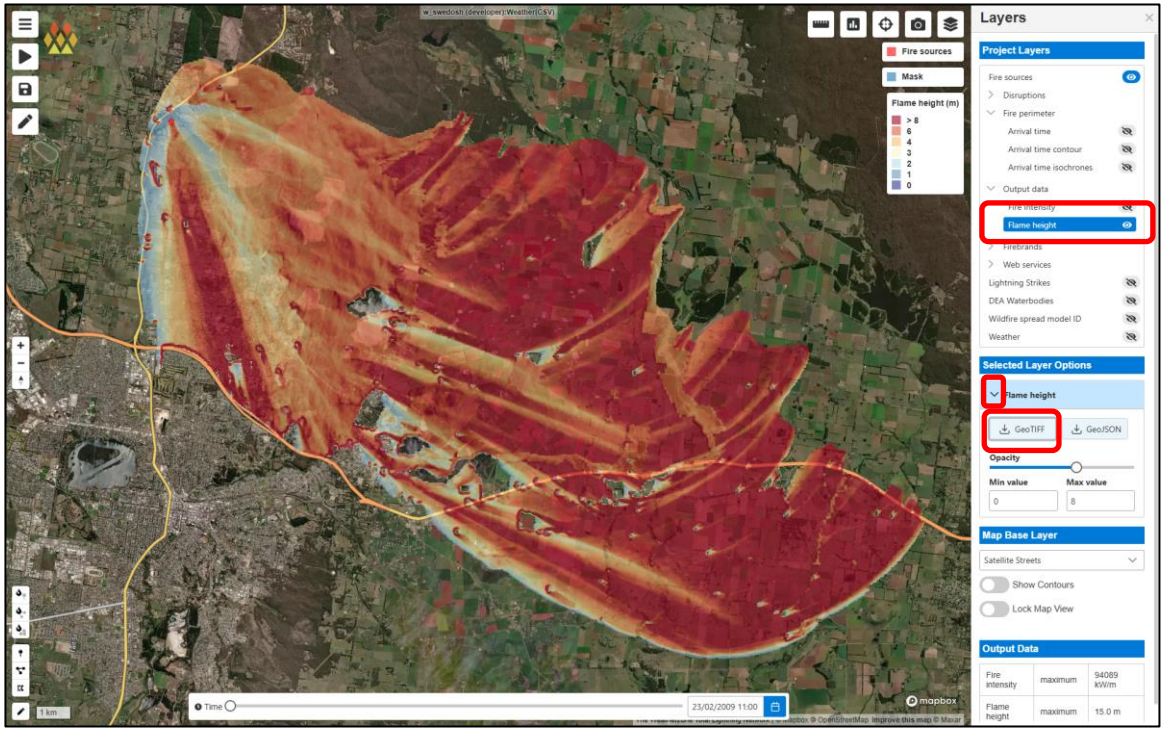
  - *Right mouse or ctrl+left mouse to rotate view*
  - *Mousewheel to zoom*
  - *View reset using compass button*
- Layer options
  - *Layer download buttons*
  - *Opacity slider*
  - *Colour map*
  - *Colour range*
- Layer download
  - *Defaults to 'Downloads' folder if no directory selected*



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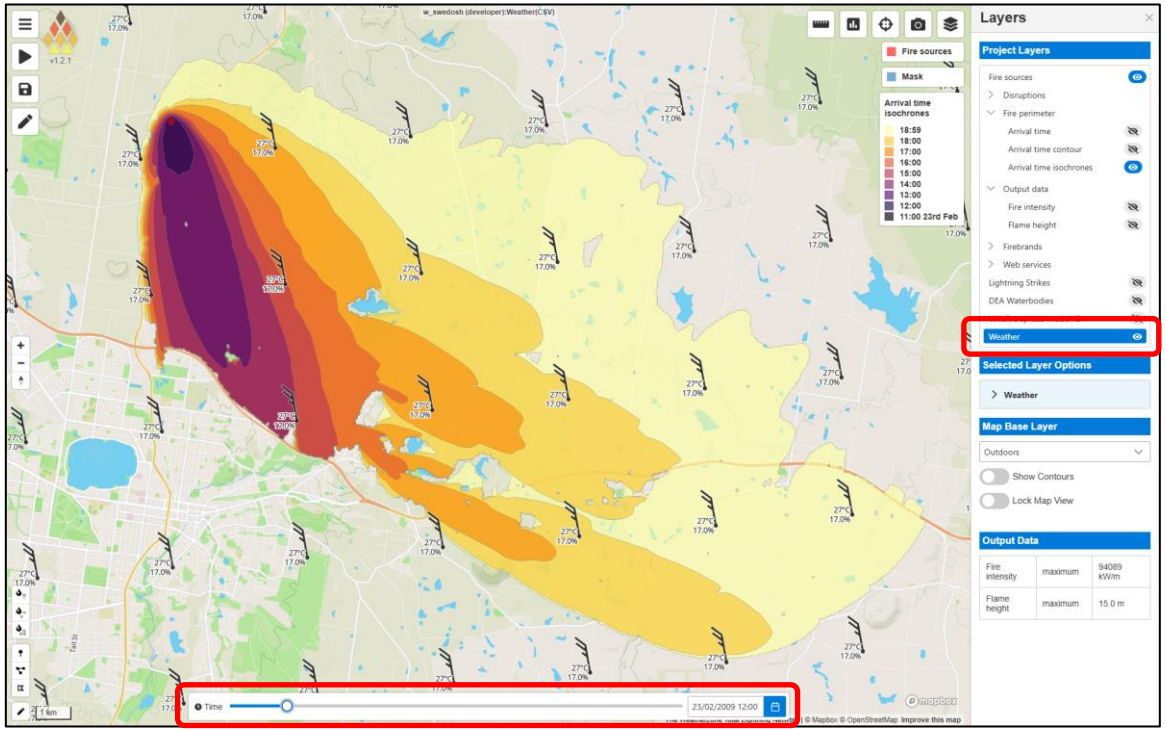
  - *View reset using compass button*
- Layer options
  - *Layer download buttons*
  - *Opacity slider*
  - *Colour map*
  - *Colour range*
- Layer download
- Weather visualisation
  - *Changes with time slider*



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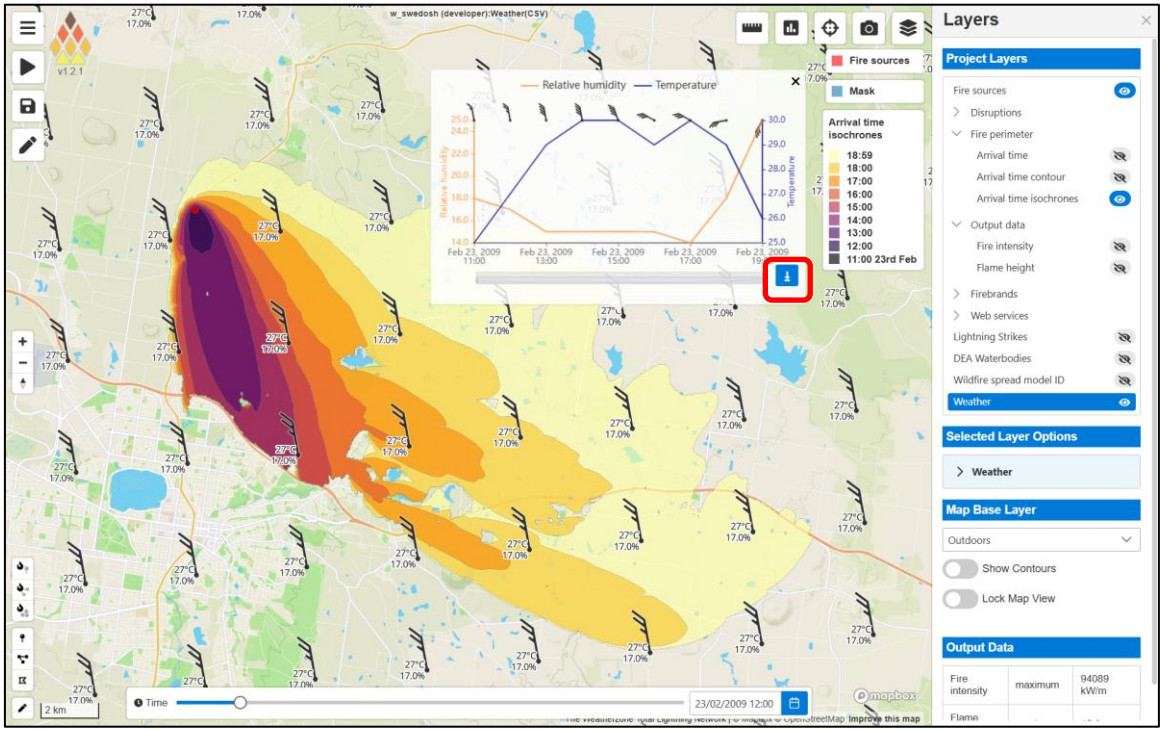
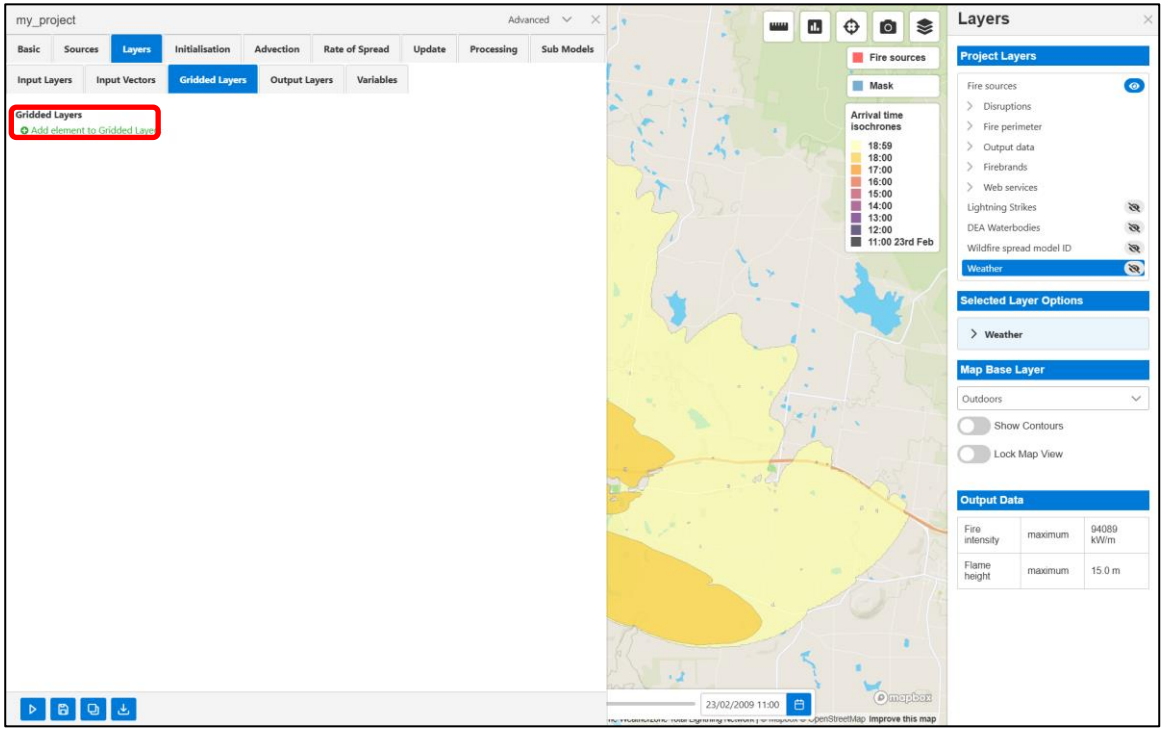
- Layer options
  - *Layer download buttons*
  - *Opacity slider*
  - *Colour map*
  - *Colour range*
- Layer download
- Weather
  - *Changes with time slider*
  - *Shows time series chart when icon is clicked*
  - *Can be downloaded as a csv*



SparkWeb

Advanced usage

- Weather inputs
  - *Spark requires whatever weather variables your rate of spread models use as inputs*
  - *Generally wind speed and direction, relative humidity and temperature*
  - *Could also include drought factor, dew temperature, curing*
  - *Can be uploaded as a set of gridded netcdf files*
  - *We have guides to use BARRA-R2, ERA5, ops_aps2 and ops_APS3 data sets for historical reconstructions*

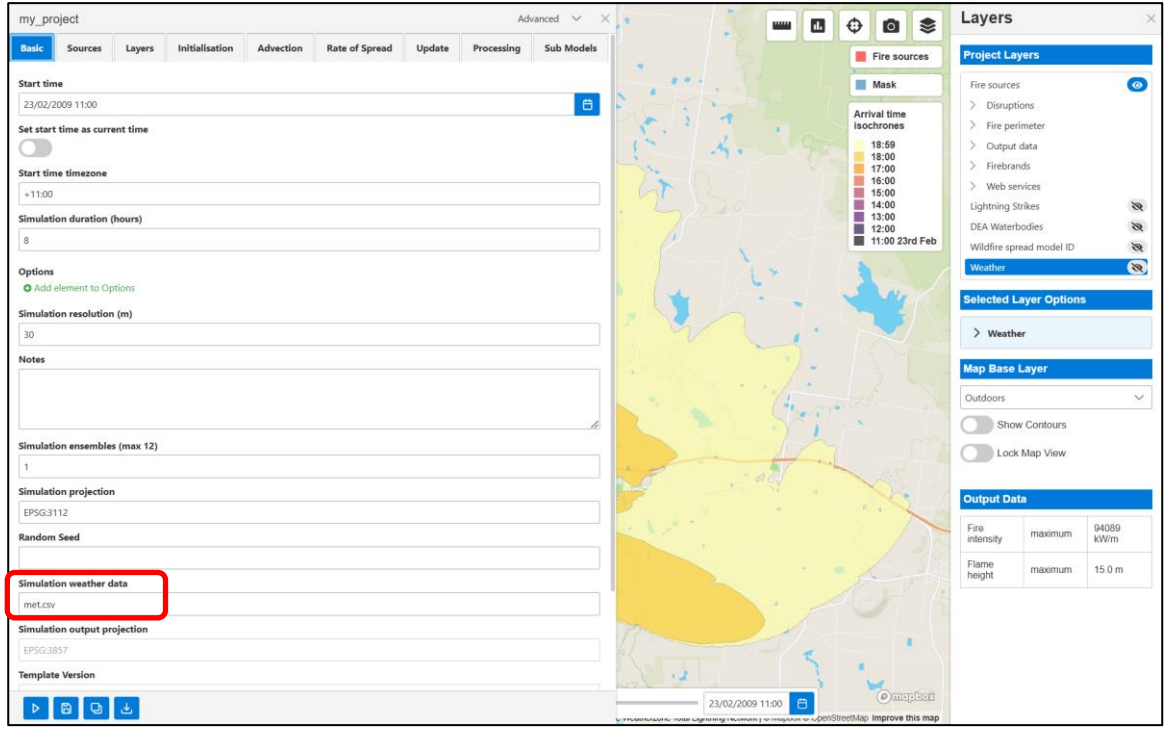


SparkWeb

Advanced usage

- Weather inputs
  - *Spark requires whatever weather variables your rate of spread models use as inputs*
  - *Generally wind speed and direction, relative humidity and temperature*
  - *Could also include drought factor, dew temperature, curing*
  - *Can be uploaded as a set of gridded netcdf files*
  - *Or a suitable weather csv file can be dragged and dropped into the 'Simulation series CSV' input*
  - *Example csv format:*

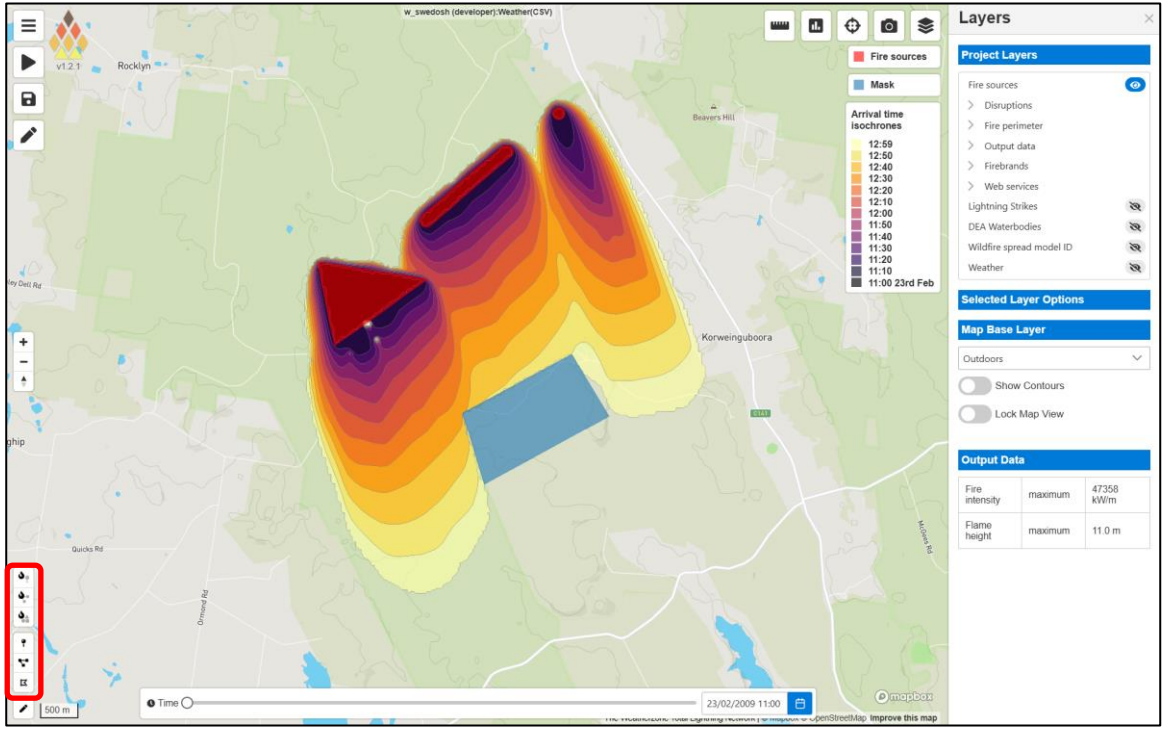
date	relative_humidity	temperature	wind_direction	wind_magnitude
2009-02-23T11:00:00+11:00	18	25	350	15
2009-02-23T12:00:00+11:00	17	27	350	25
2009-02-23T13:00:00+11:00	15	29	350	39
2009-02-23T14:00:00+11:00	15	30	350	39
2009-02-23T15:00:00+11:00	15	30	340	39
2009-02-23T16:00:00+11:00	15	29	300	30
2009-02-23T17:00:00+11:00	14	30	300	33
2009-02-23T18:00:00+11:00	18	29	260	33
2009-02-23T19:00:00+11:00	25	26	210	30



SparkWeb

Advanced usage

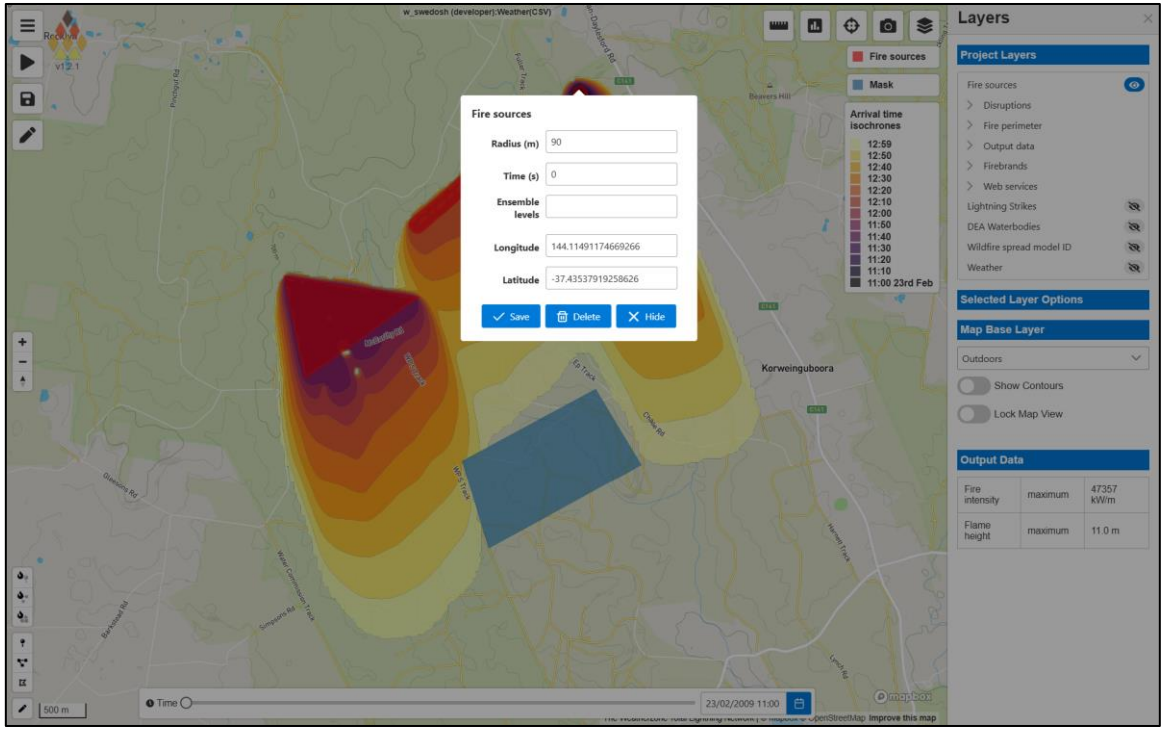
- Input tools
  - *Point fire creation*
  - *Line fire creation*
  - *Polygon fire creation*
  - *Mask creation (un-burnable by default, but can be used to modify input values)*



SparkWeb

Advanced usage

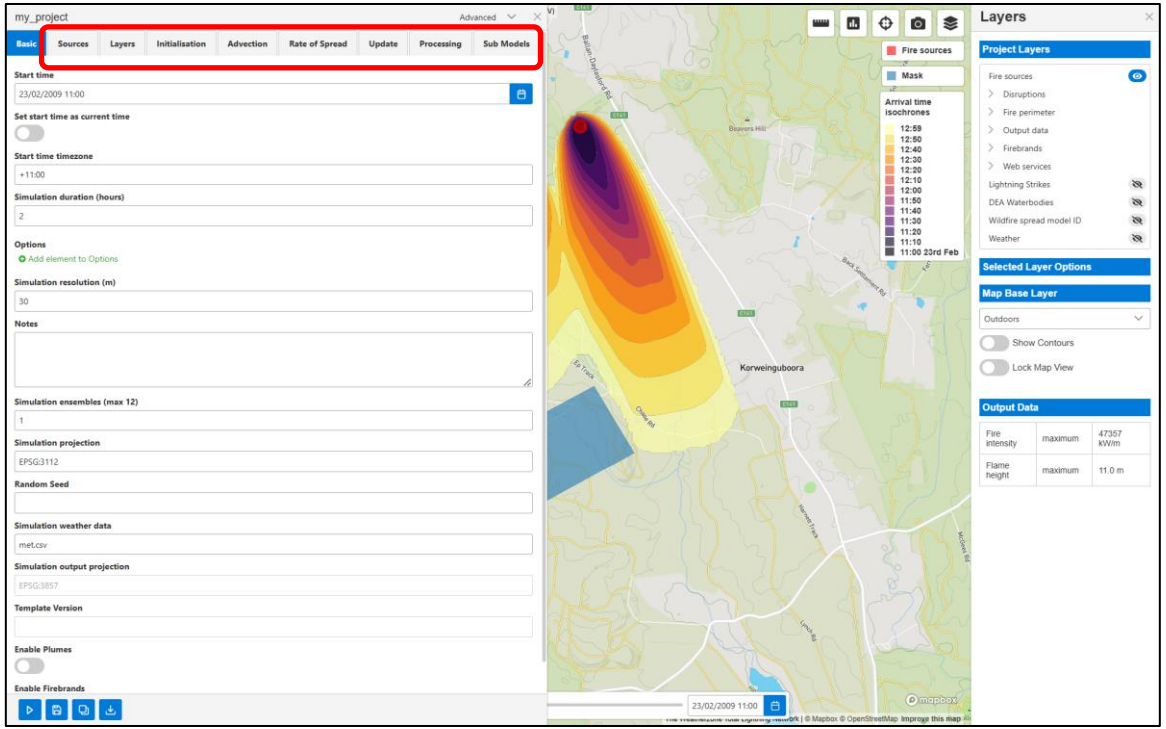
- Input tools
  - *Point fire creation*
  - *Line fire creation*
  - *Polygon fire creation*
  - *Mask (un-burnable) creation*
- Multiple ignitions
  - *Different start times*
  - *Left-click to configure*
  - *Set geometry properties*
  - *Set ignition time*
  - *Set position*



SparkWeb

Advanced usage

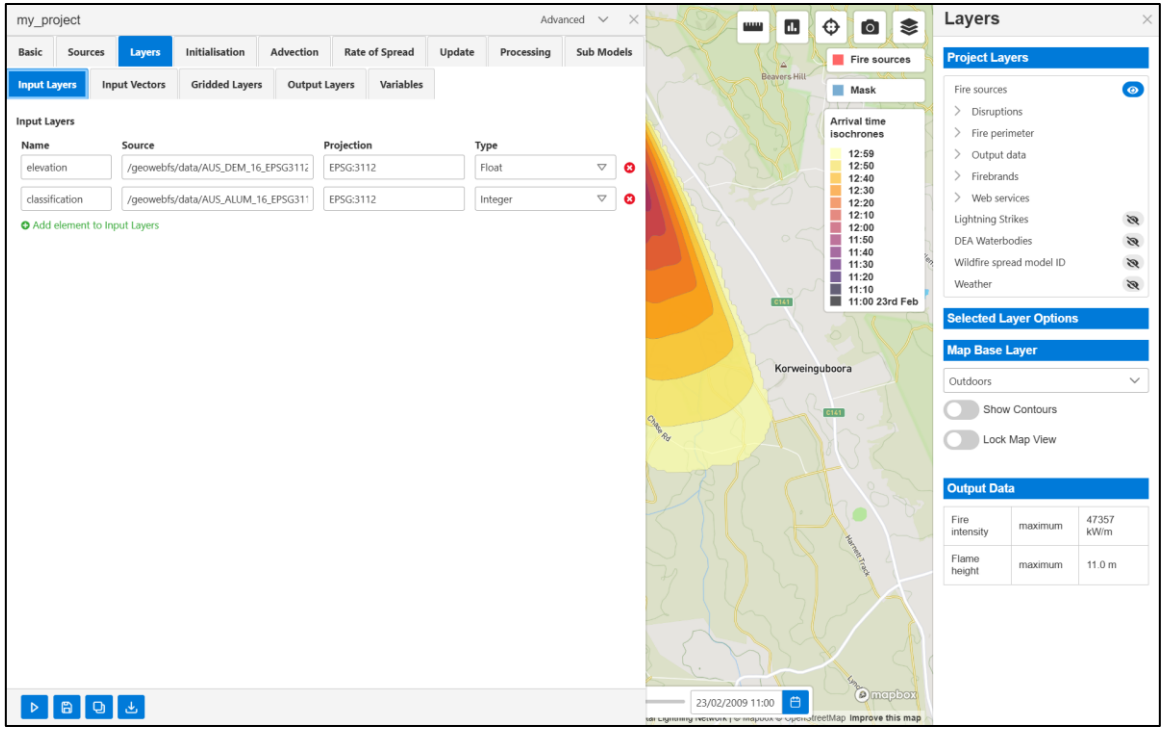
- Advanced options
  - *All layers and options available*



SparkWeb

Advanced usage

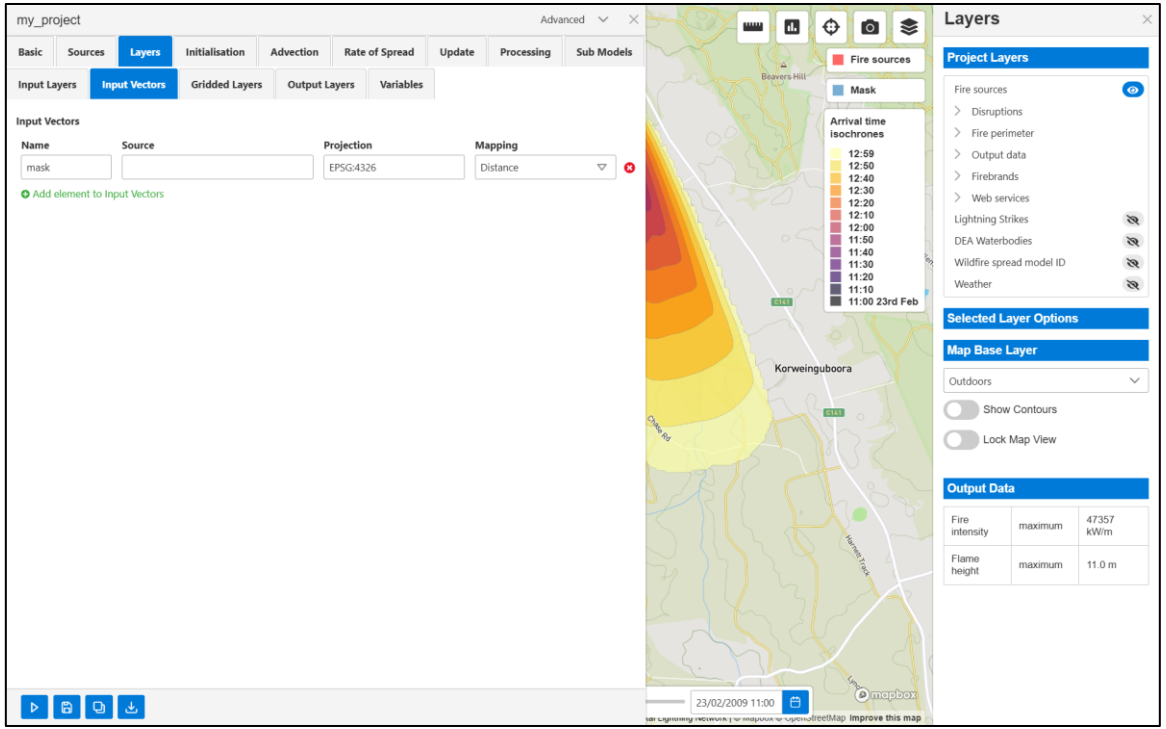
- Advanced options
  - *All layers and options available*
- Layers
  - *Input layers – Land classification, elevation, fuel age, disruptions…*



SparkWeb

Advanced usage

- Advanced options
  - *All layers and options available*
- Layers
  - *Input layers – Land classification, elevation, fuel age, disruptions…*
  - *Vector layers – Can be used to overwrite input layers or set unburnable areas by drawing lines / polygons*



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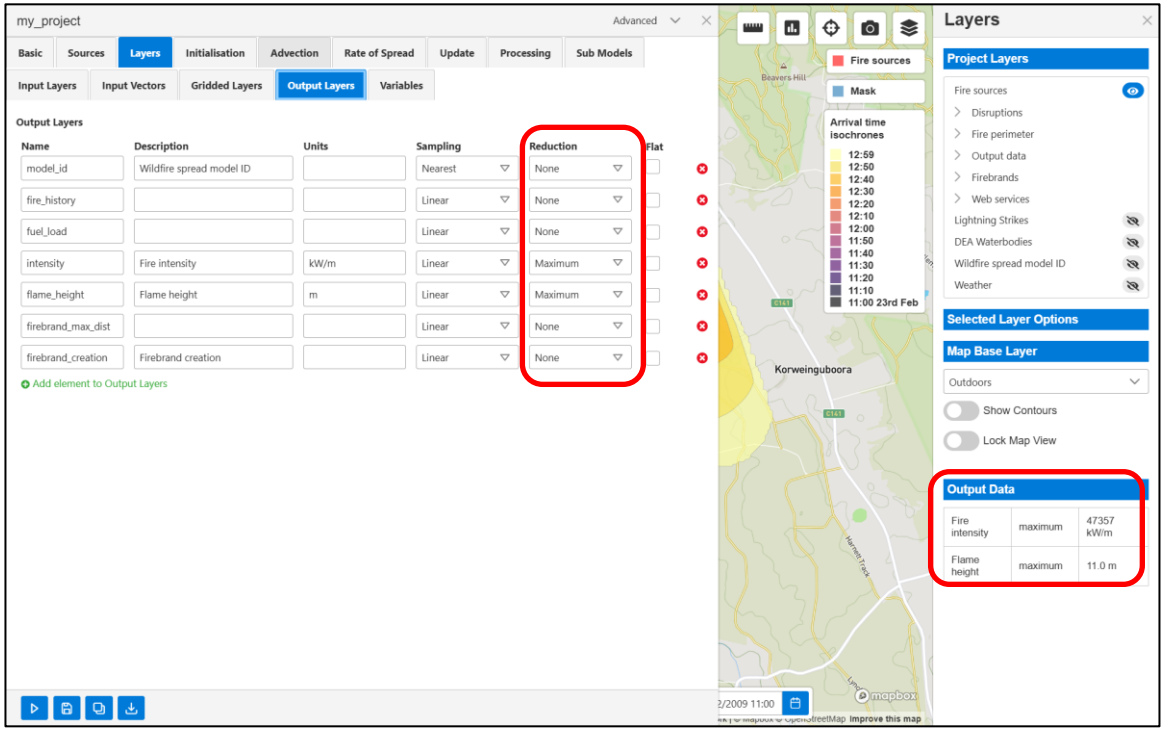
Advanced usage

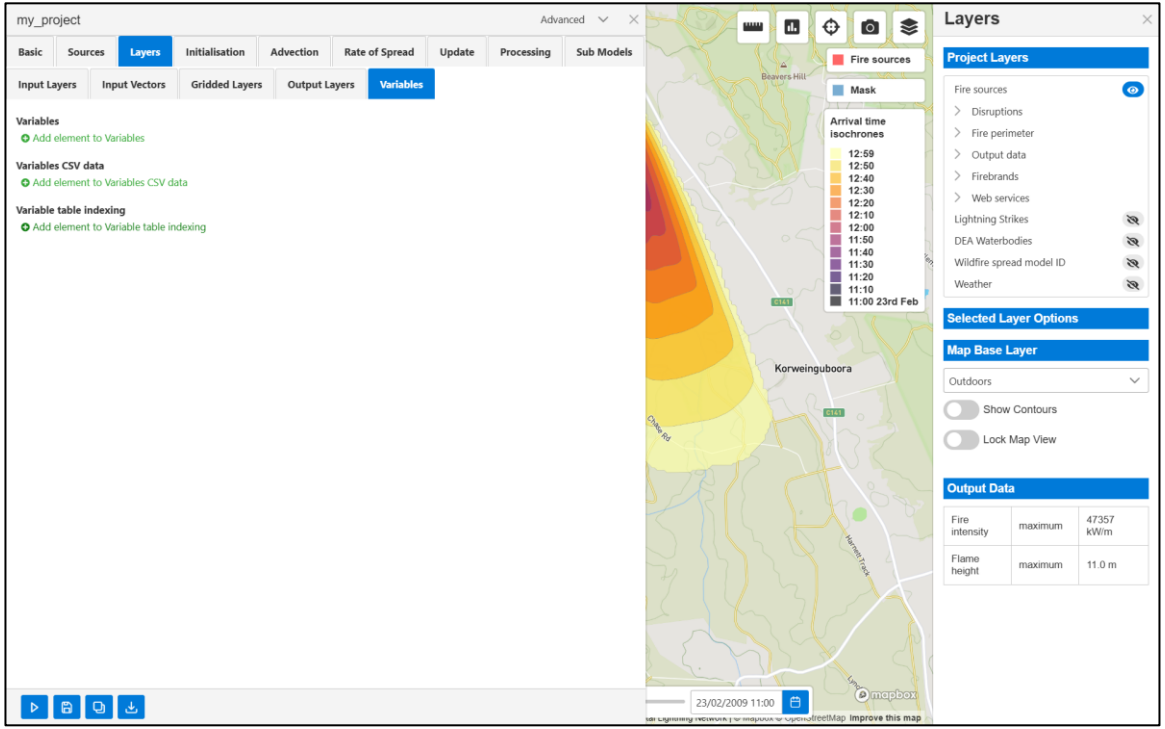
- Advanced options
  - *All layers and options available*
- Layers
  - *Input layers – Land classification, elevation, fuel age, disruptions…*
  - *Vector layers – Can be used to overwrite input layers or set unburnable areas by drawing lines / polygons*
  - *Gridded layers – Meteorological netcdf files*
  - *Output layers – Creates rasters which can be written to in initialisation, rate of spread or output models. Any with descriptions are visualised in Project Layers after simulation is run. Reductions shown in Output Data table at completion of simulation*



SparkWeb

Advanced usage

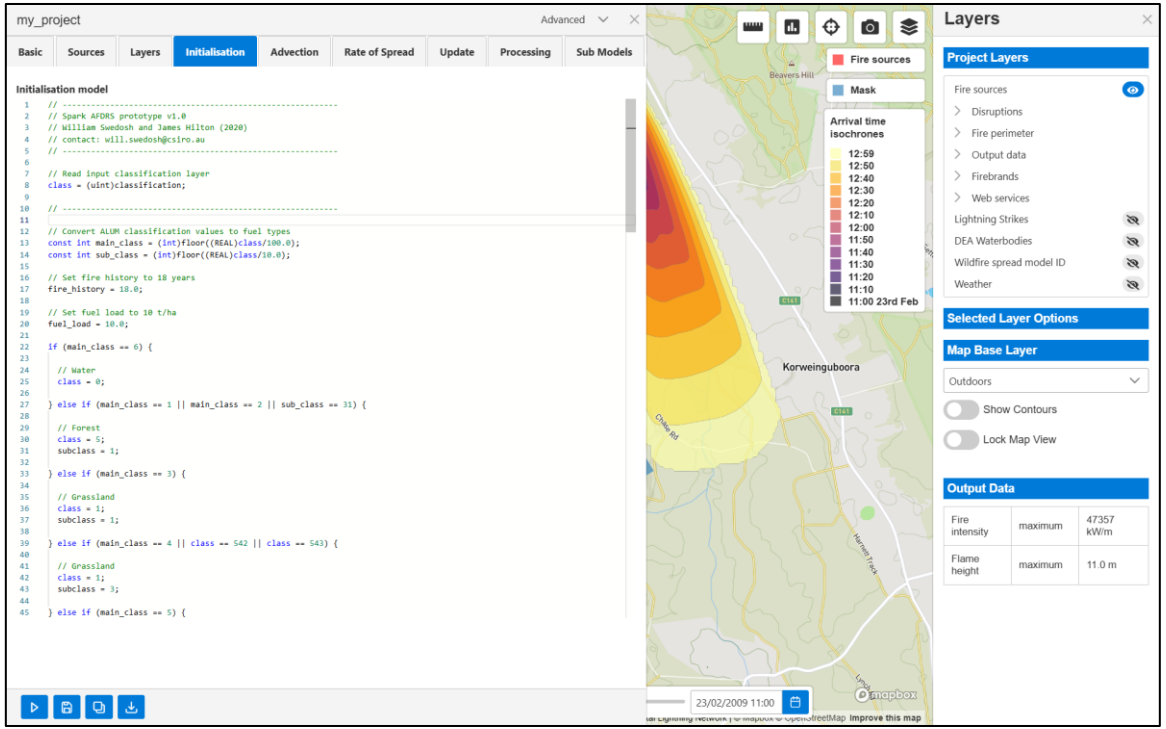
- Advanced options
  - *All layers and options available*
- Layers
  - *Input layers – Land classification, elevation, fuel age, disruptions…*
  - *Vector layers – Can be used to overwrite input layers or set unburnable areas by drawing lines / polygons*
  - *Gridded layers – Meteorological netcdf files*
  - *Output layers – Creates rasters which can be written to in initialisation, rate of spread or output models. Any with descriptions are visualised in Project Layers after simulation is run. Reductions shown in Output Data table at completion of simulation*
  - *Variables – Can be used to set global variables for a simulation. CSV data can be uploaded and used as a look up table (e.g. for fuel attributes)*



SparkWeb

Advanced usage

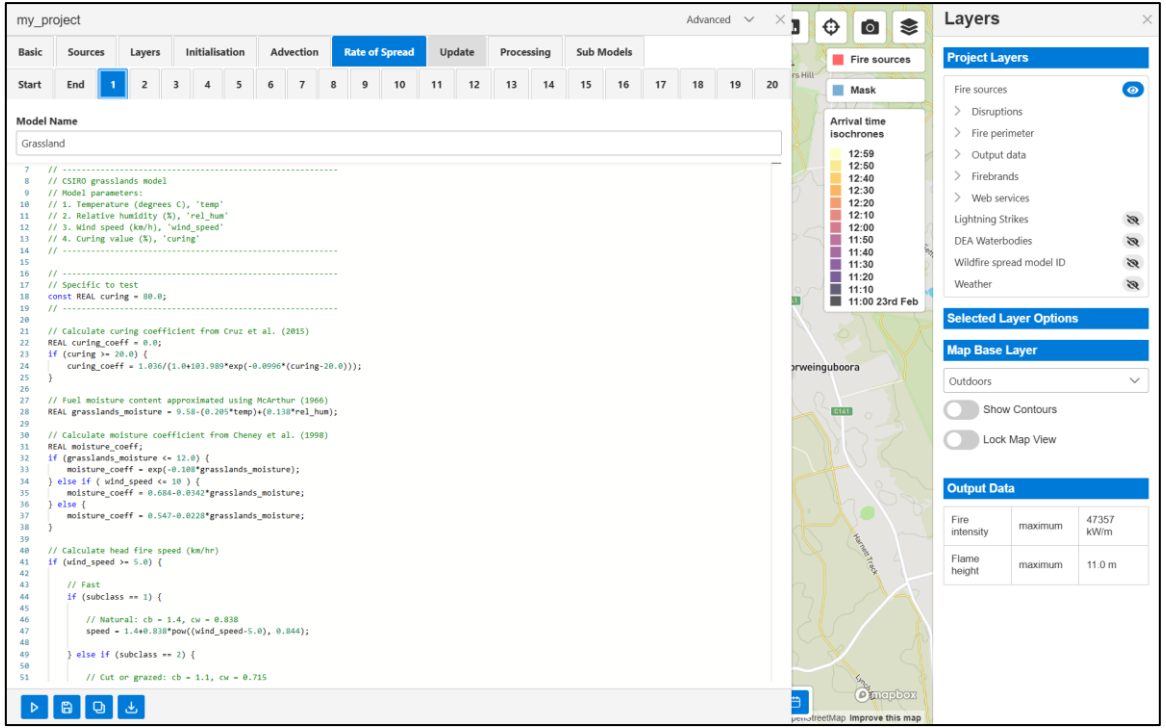
- Models
  - *Initialisation - Run once per cell. Can be used to set rate of spread model, fuel parameters etc. from input data*



SparkWeb

Advanced usage

- Models
  - *Initialisation - Run once per cell*
  - *Advection - Used to modify wind field via advect_x and advect_y variables (EW and NS wind speed components)*
  - *Rate-of-spread, run to determine outward speed. 'Start' runs first for all models and is often used to calculate slope effects. Individual models are then run (for their respective grid cells), often to calculate head fire rate-of-spread. 'End' is then run which often applies the slope effect and applies a geometric template to spread the fire in 2D.*



SparkWeb

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  - *Initialisation - Run once per cell*
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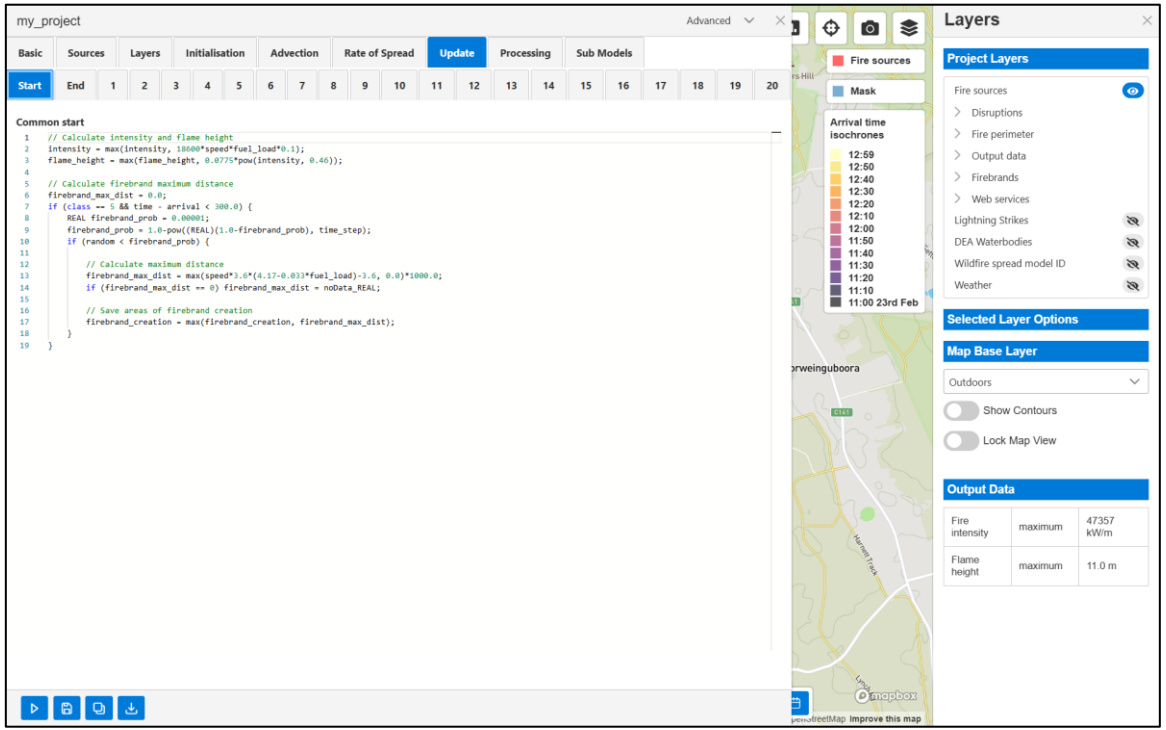
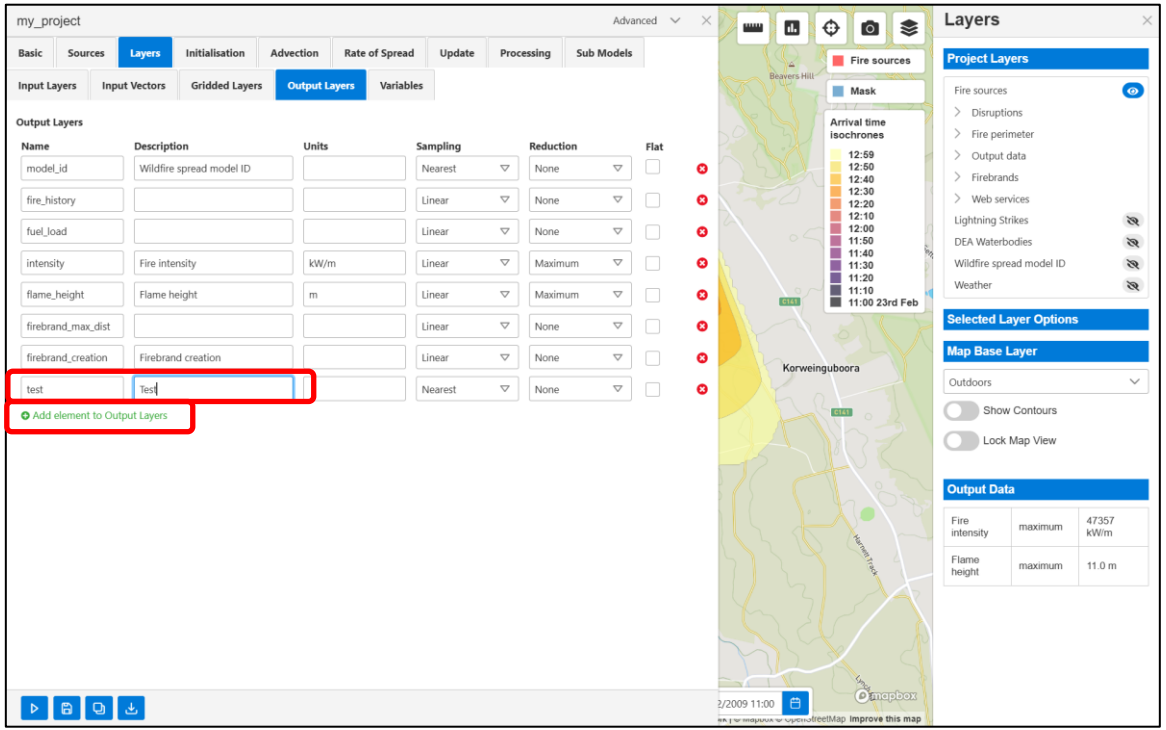
  - *Update, runs within burnt regions. ‘Start’ runs first for all models. Individual models are then run (for their respective grid cells), often to calculate flame height and fireline intensity. ‘End’ is then run for all models which often calculates effects of disruptions.*



SparkWeb

Advanced usage

- Layer creation
  - *Any number can be created*
  - *Name available in model scripts for reading/writing*
  - *Must have description to be visualised*
  - *Example ‘test’ layer created called ‘Test’*



SparkWeb

Advanced usage

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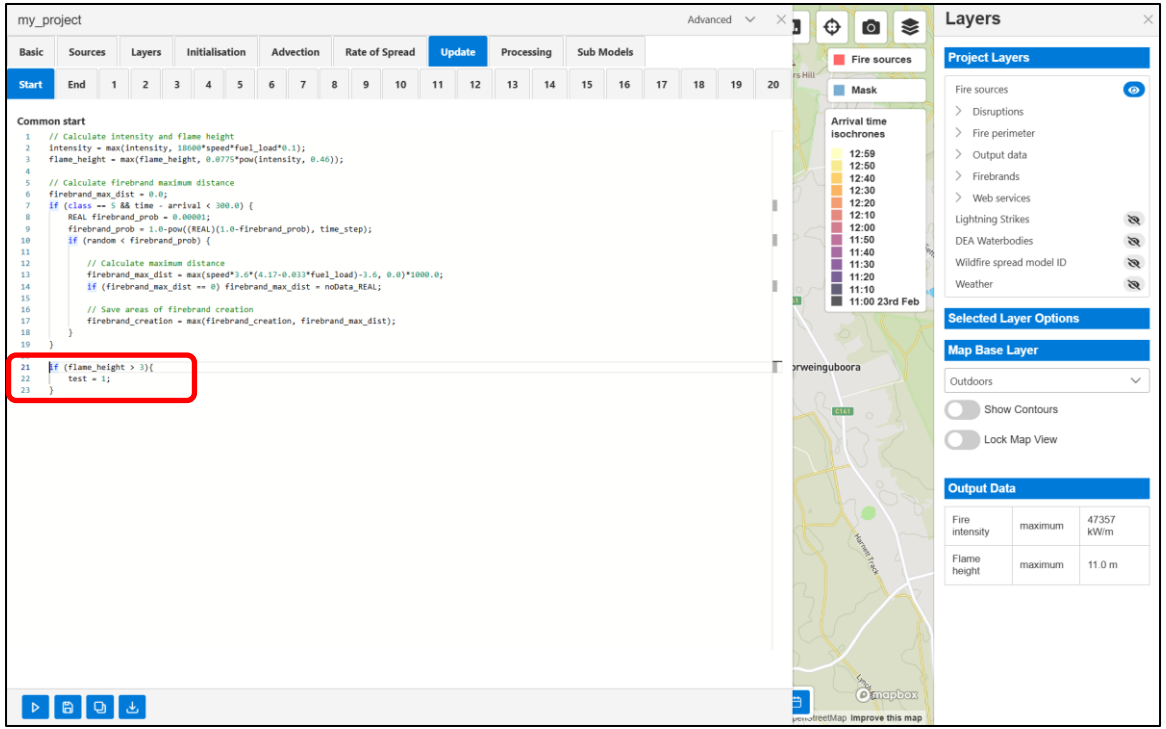
  - *Any number can be created*
  - *Name available in model scripts for reading/writing*
  - *Must have description to be visualised*
  - *Example ‘test’ layer created called ‘Test’*
- Scripting
  - *Layer is written in update model*
  - *Anywhere where flame height > 3 test is 1*
  - *Elsewhere test is null*



SparkWeb

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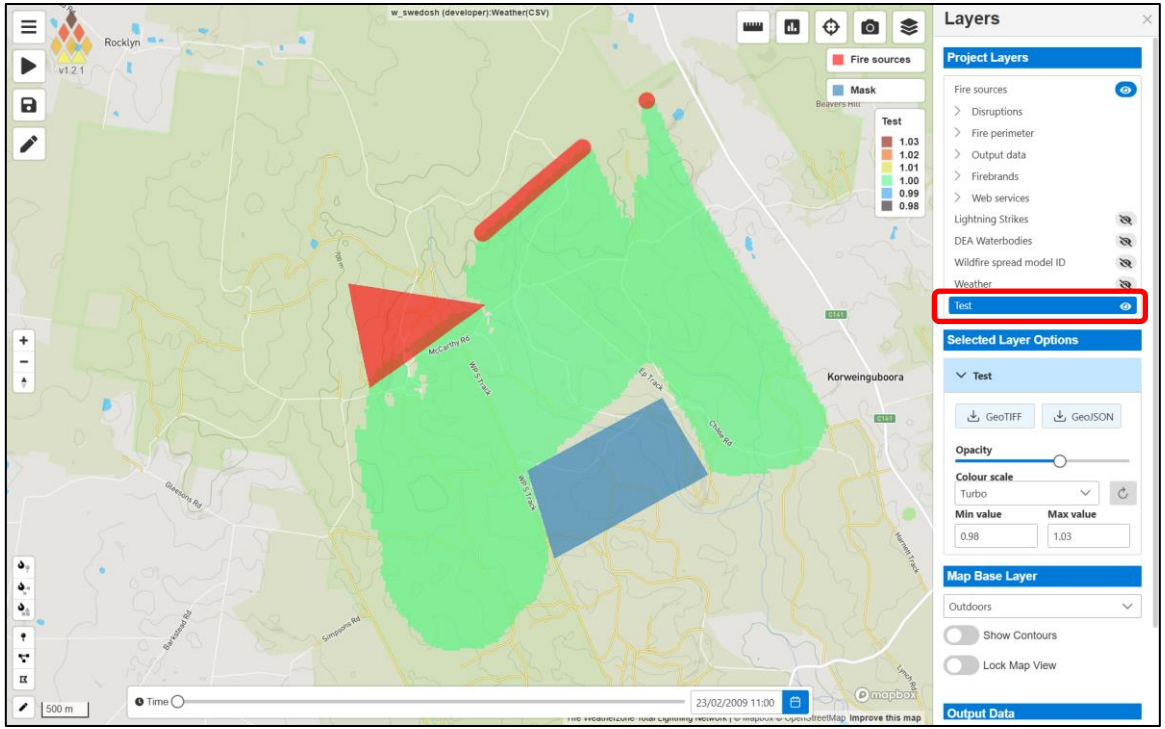
  - *Data from ‘Test’ shown in green after simulation is run again*



SparkWeb

Advanced usage

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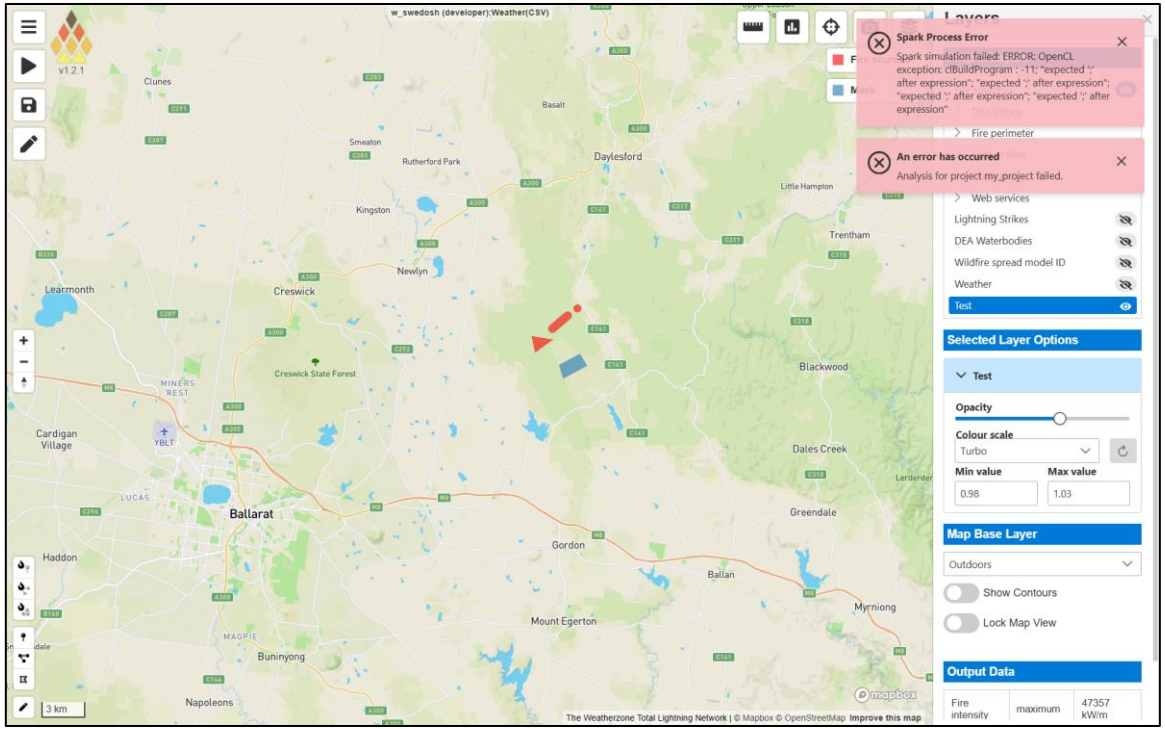
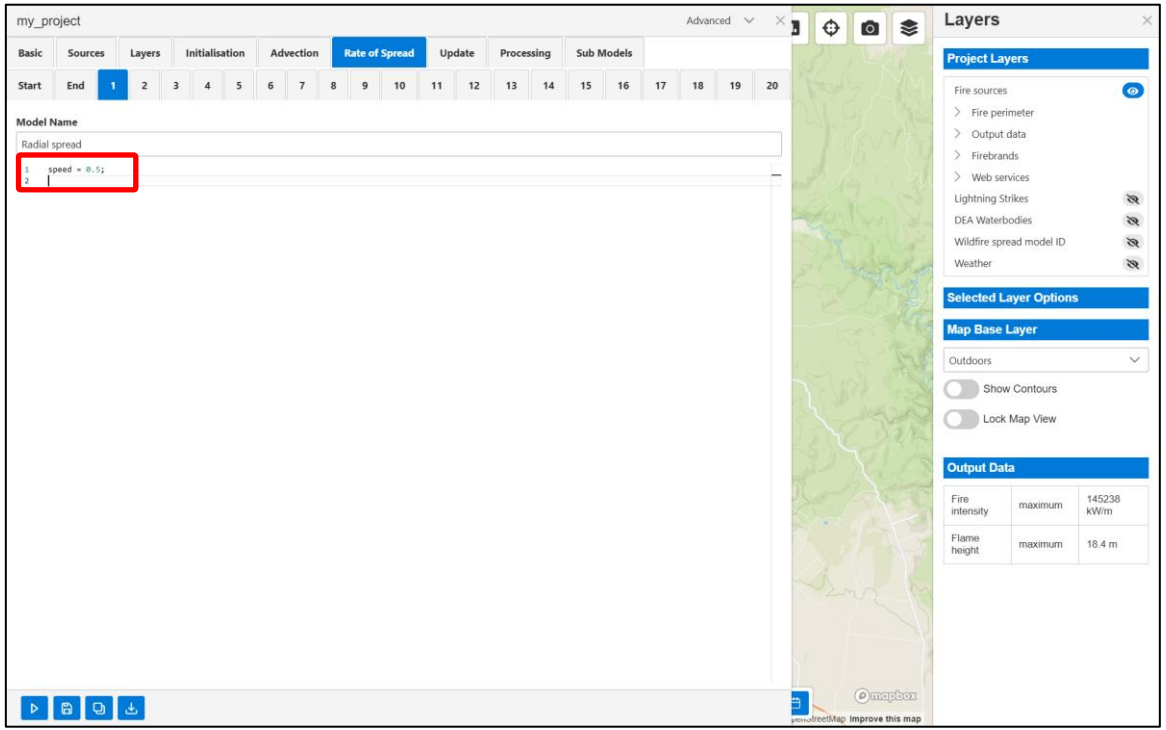
  - *Any number can be created*
  - *Name available in model scripts for reading/writing*
  - *Must have description to be visualised*
  - *Example ‘test’ layer created called ‘Test’*
- Scripting
  - *Layer is written in update model*
  - *Anywhere where flame height > 1 test is 1*
  - *Elsewhere test is null*
- Visualisation
  - *Data from ‘Test’ shown in green after simulation is run again*
- Errors
  - *Errors appear in a red box*
  - *Script errors trigger ‘Spark simulation failed’*
  - *Reported as a ‘clBuildProgram: -11’ exception*
  - *We will make this more intelligible!*
  - *The full error log is available in the API response*



SparkWeb

Advanced usage

- Rate-of-spread scripts
  - *Script for each fuel classification type*
  - *Each type is an integer identifier ‘class’*
  - *Zero is reserved for un-burnable*
  - *Classes can be named*



SparkWeb

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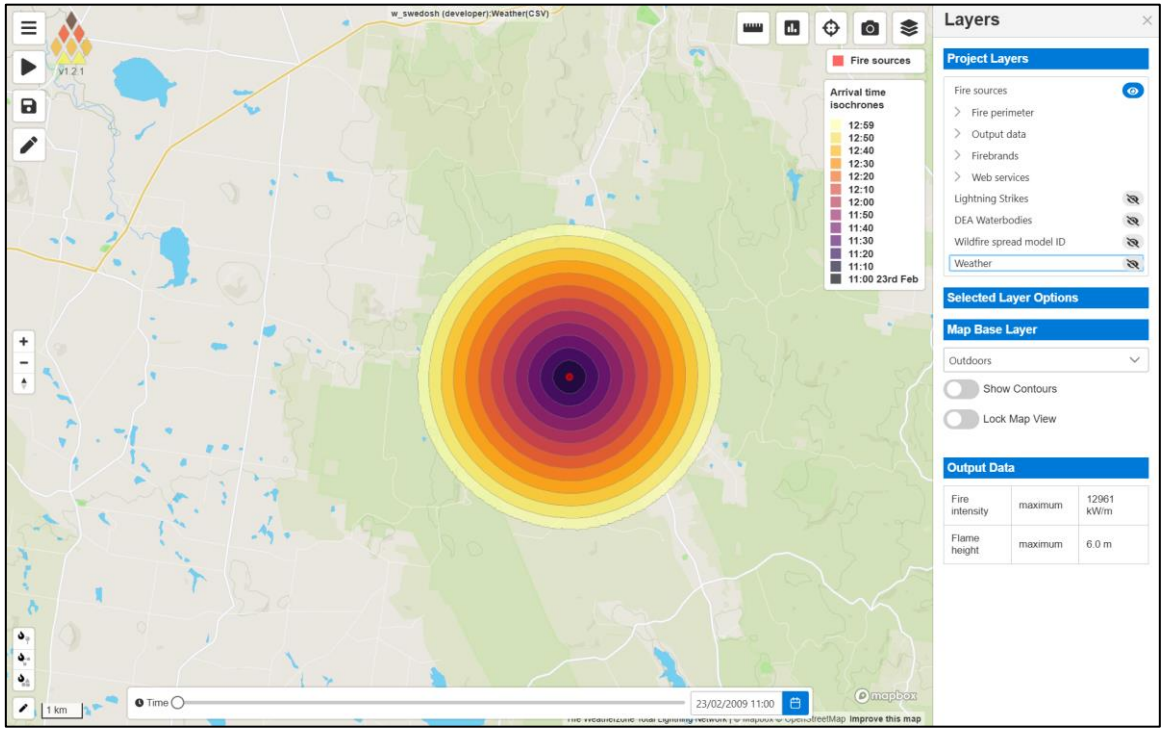
- Example 1
  - *Script “speed = 0.5;”*
  - *Sets outward speed to 0.5 m/s*
  - *Resulting fire is circular*



SparkWeb

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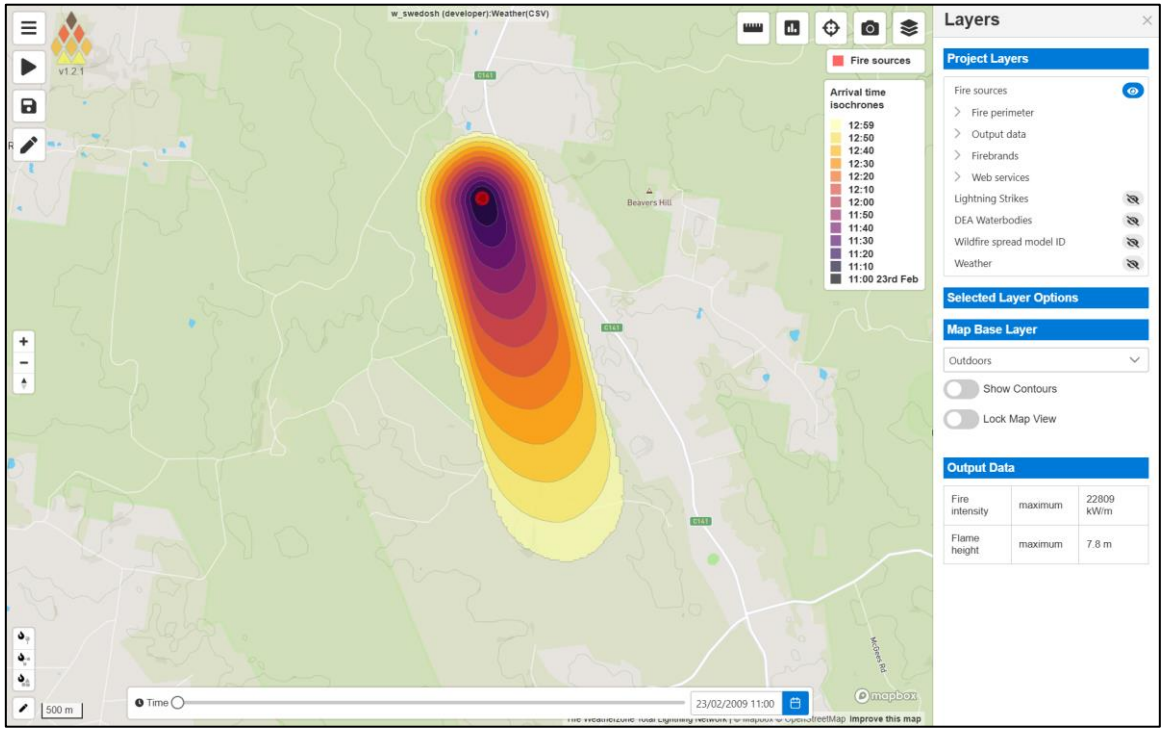
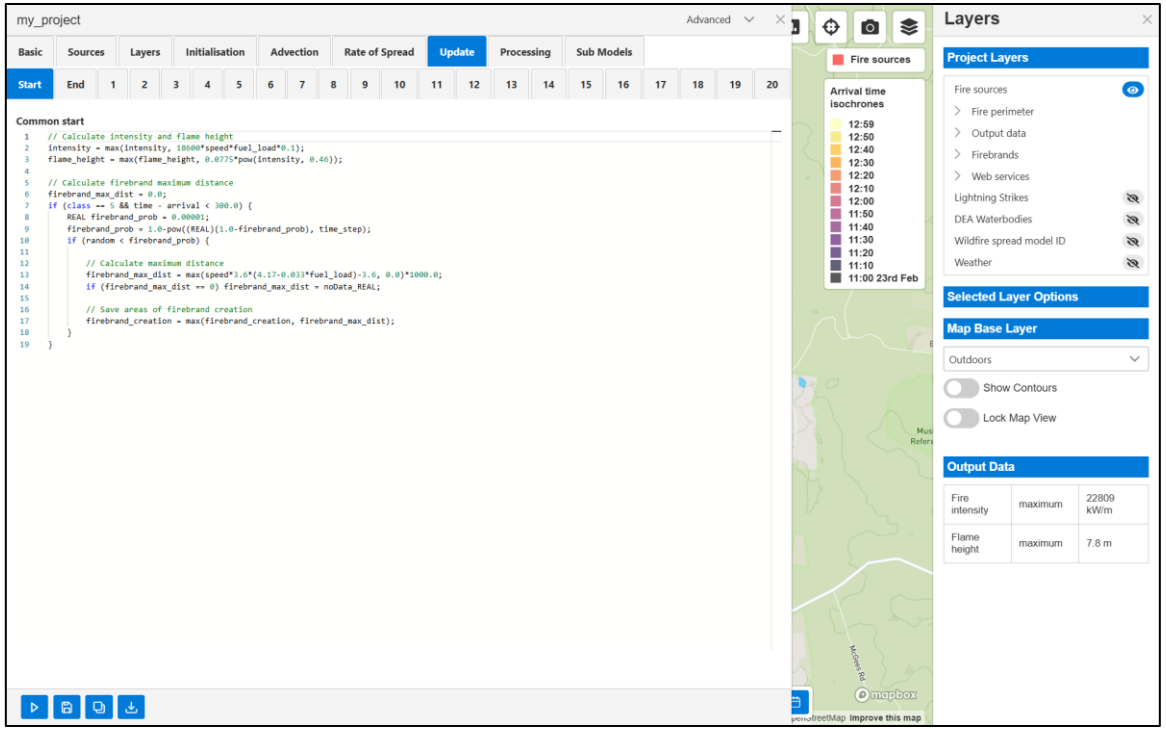
  - *Script “speed = 0.5;”*
  - *Sets outward speed to 0.5 m/s*
  - *Resulting fire is circular*
- Example 2
  - *Script “speed = 0.1+0.02*wind;”*
  - *Adds component in wind direction*
  - *Resulting fire grows outwards and moves with wind*



SparkWeb

Advanced usage – Sub Models

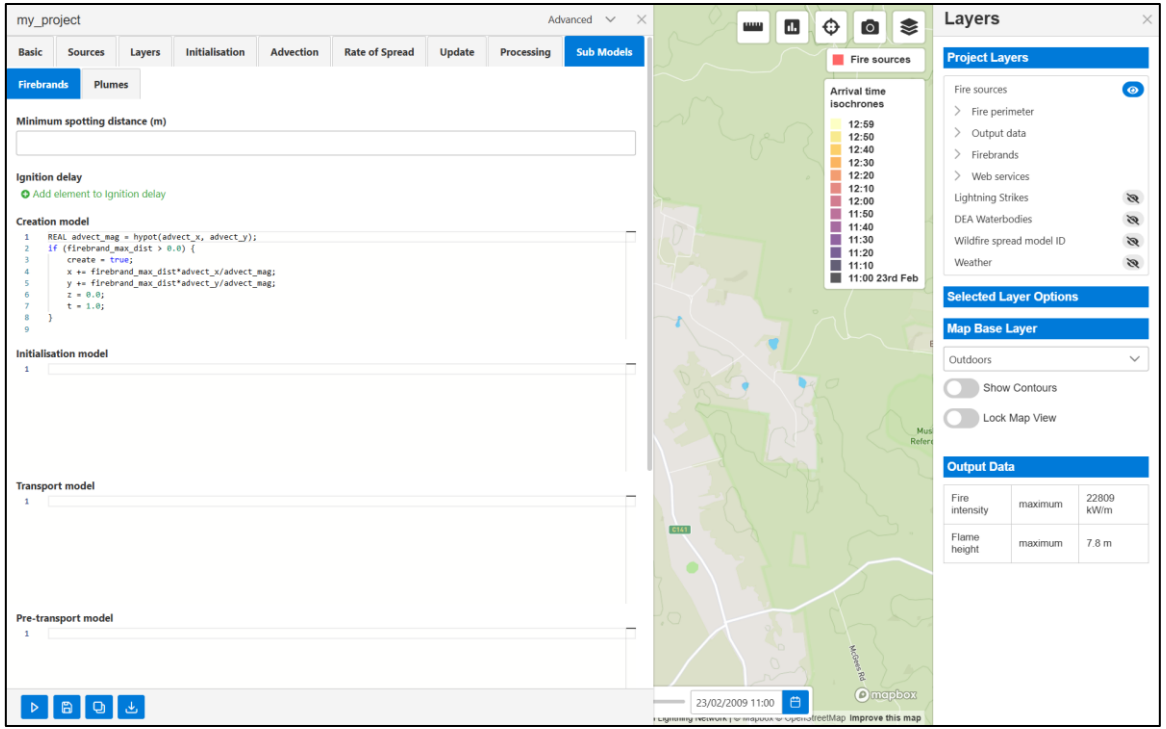
- Firebrand model
  - *Eucalypt forest empirical firebrand model*
  - *Requires script (update model) to determine creation*



SparkWeb

Advanced usage – Sub Models

- Firebrand model
  - *Eucalypt forest empirical firebrand model*
  - *Requires script to determine creation*
  - *Models for all firebrand stages*
  - *Creation script, sets new firebrand positions*
  - *Initialisation script, creates firebrands*
  - *Advection model, controls air flow*
  - *Update model, controls firebrand changes*
  - *Transport model, controls interaction with air flow*
  - *Basic spot fire creation only required one model*



SparkWeb

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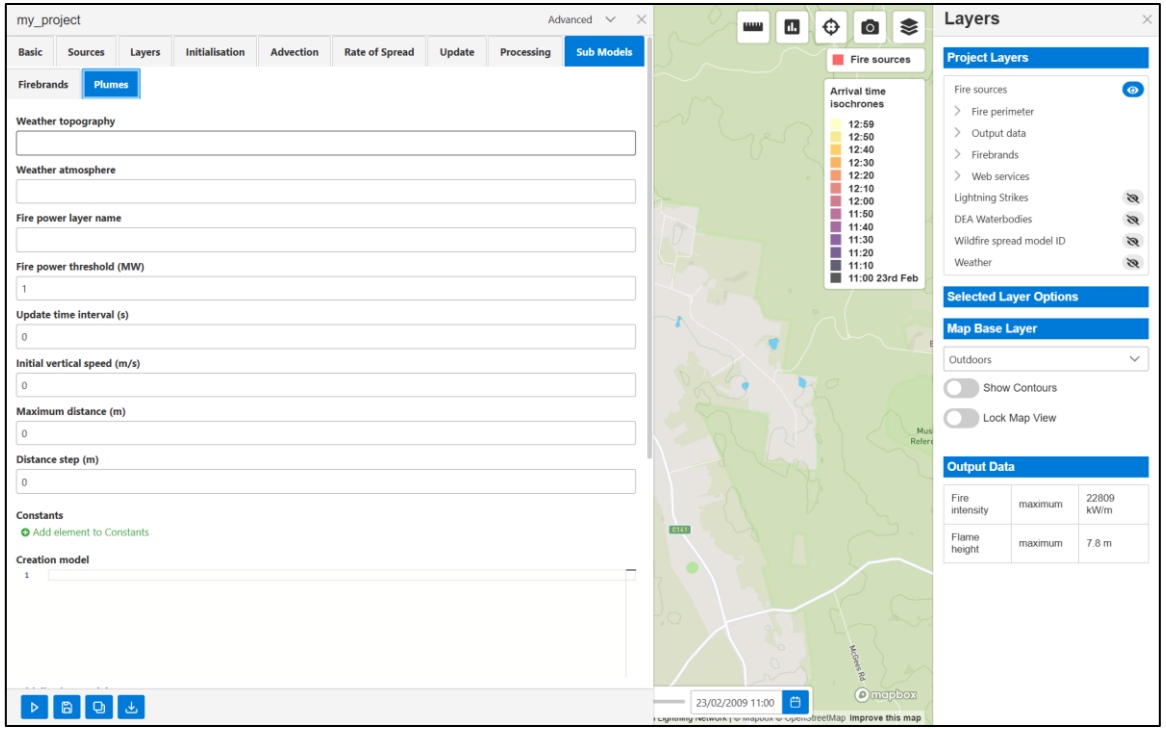
  - *Transport model, controls interaction with air flow*
  - *Basic spot fire creation only required one model*
- Plume model
  - *More physical basis for the transport of firebrands in a plume*
  - *Requires most of the physics based models above*
  - *Currently requires 3D weather layers. Simple plume model in development path*



SparkWeb

Advanced usage – Sub Models

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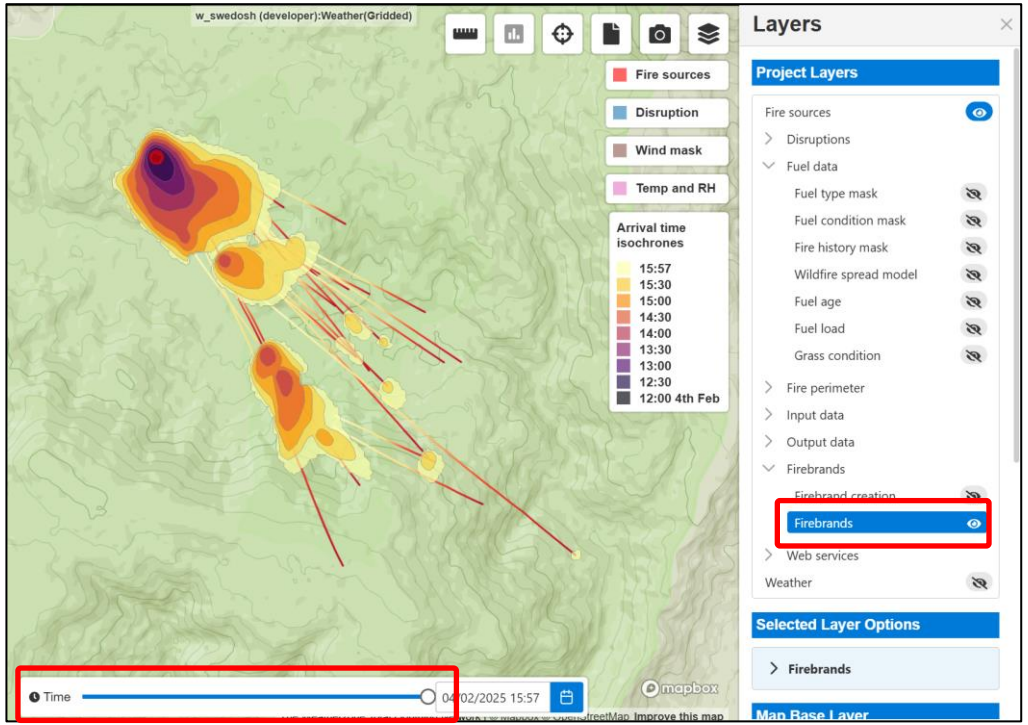
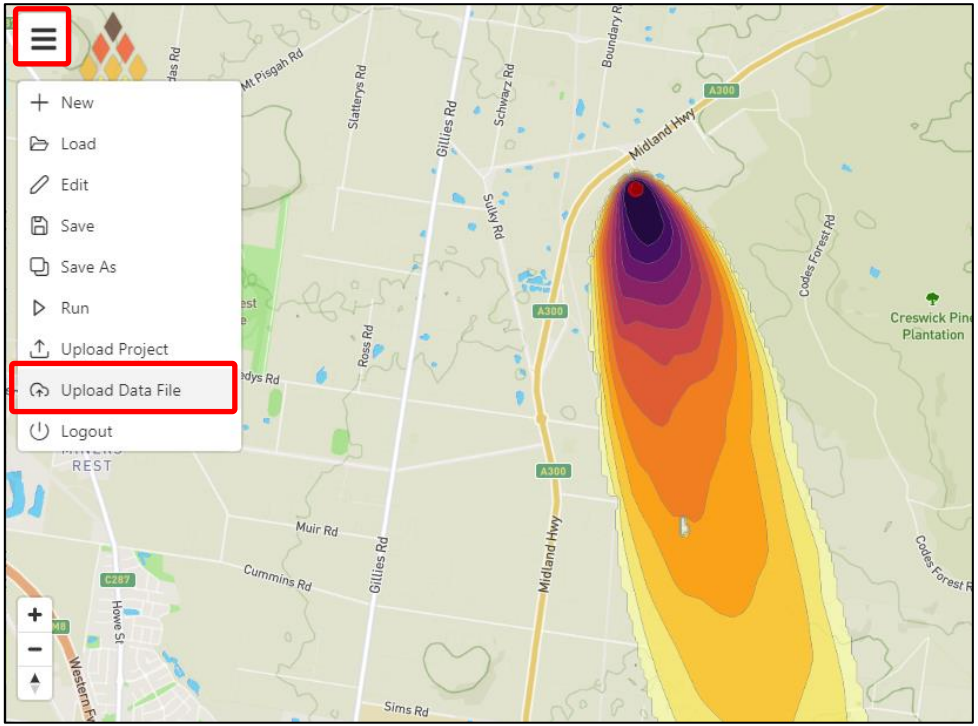
  - *Requires most of the physics based models above*
  - *Currently requires 3D weather layers. Simple plume model in development path*
- Visualisation
  - *Firebrands which cause spot fires are visualised with yellow/red lines from generation to landing points*



SparkWeb

Advanced usage

- Uploading user data layers
  - *Note, the wildfire platform is currently open. Do not upload any sensitive data as other users will be able to use it. Please use specific filenames to ensure no duplicates (e.g. MY_USER_land_classification_EPSG_XXXX_v1.tiff)*



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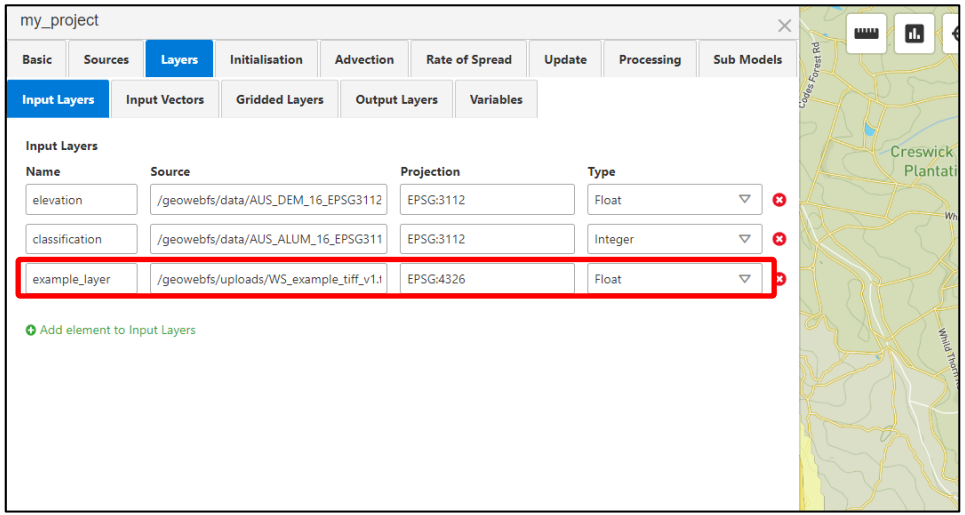
  - *File is uploaded with the path: /geowebfs/uploads/FILENAME*
  - *Input the correct projection and data type as well as a name which can be referred to in the model scripts.*



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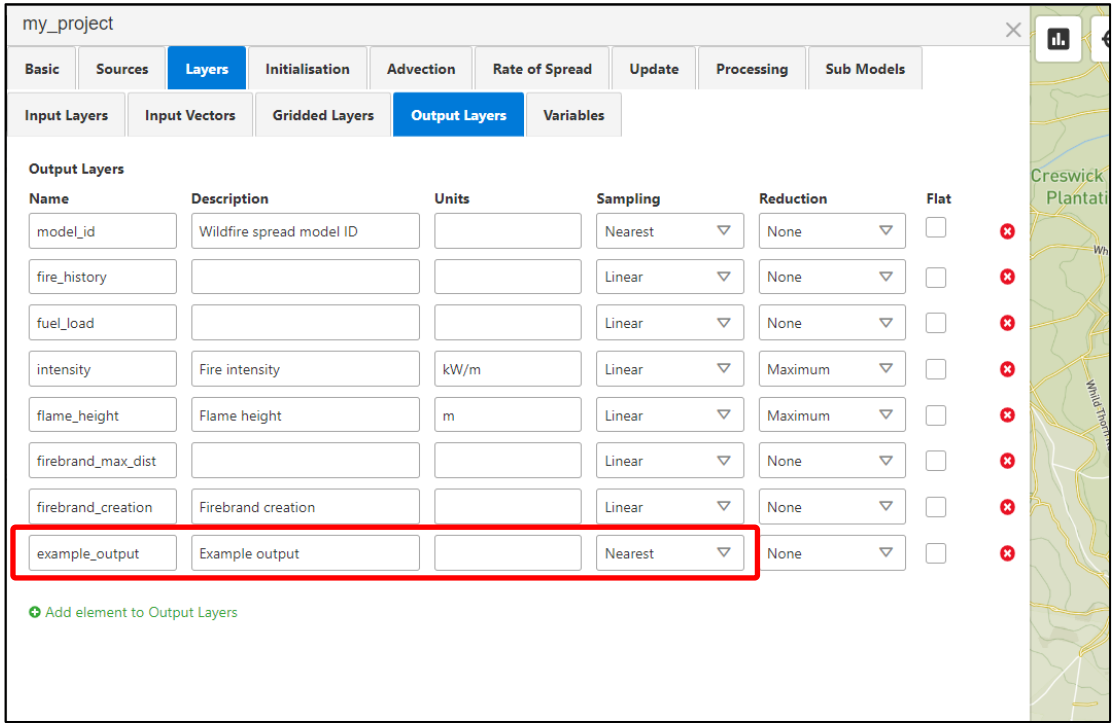
- Visualising user data layers
  - *Create an output layer*



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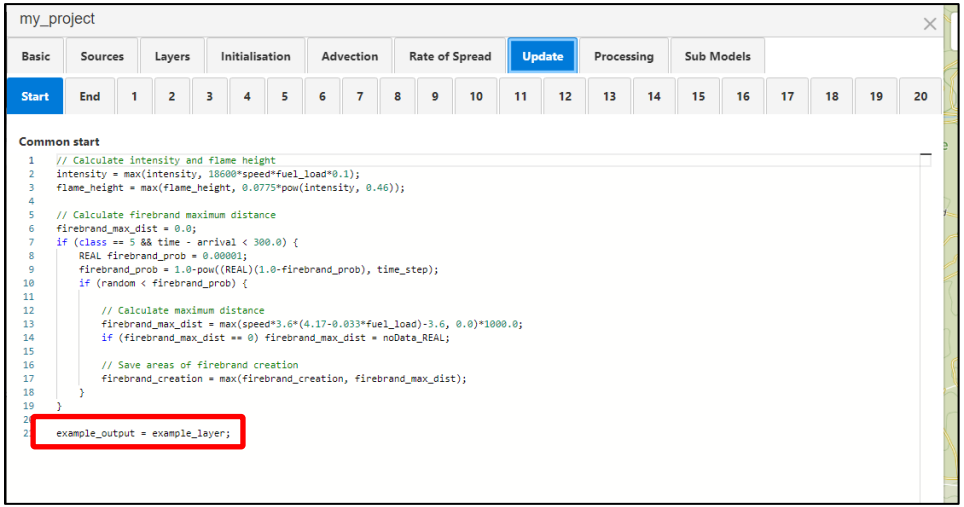
  - *Create an output layer*
  - *Write to the output in a model script*



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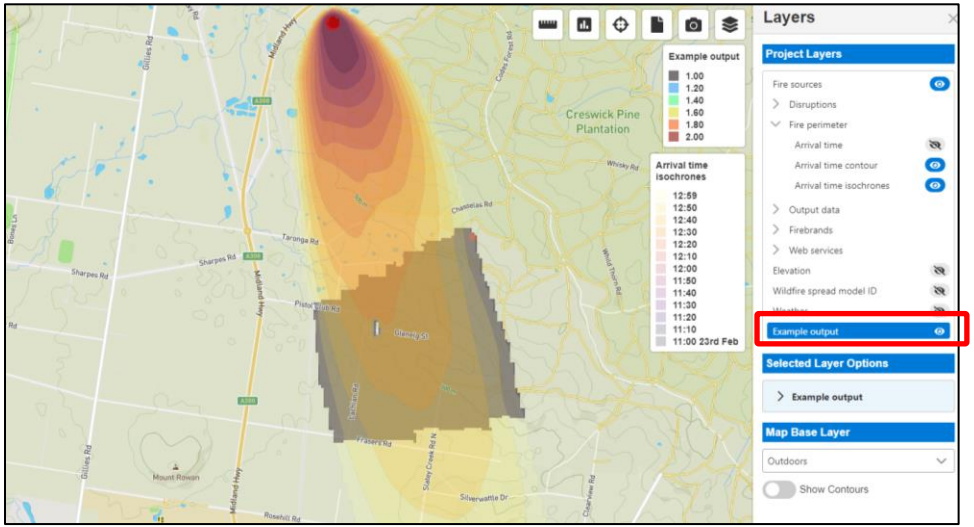
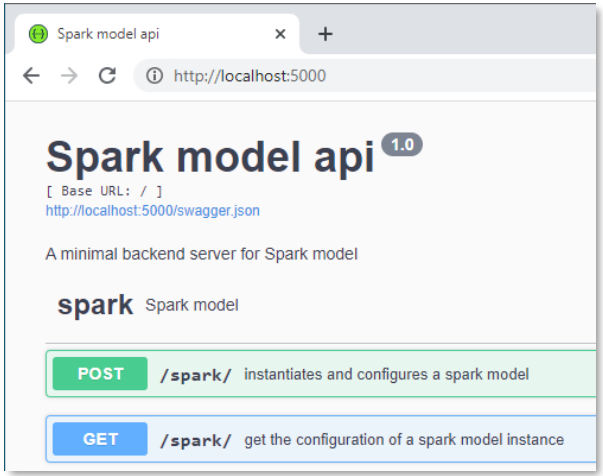
- Visualising user data layers
  - *Create an output layer*
  - *Write to the output in a model script*
  - *Run simulation again to view output*
  - *Your layer name can be used in Initialisation, Rate of Spread and Update models*



SparkWeb

Spark server

- Web API
  - *Services calls from SparkWeb*
  - *Can be called directly to run simulations/serve outputs*
  - *All models sent to server*



SparkWeb

Spark server

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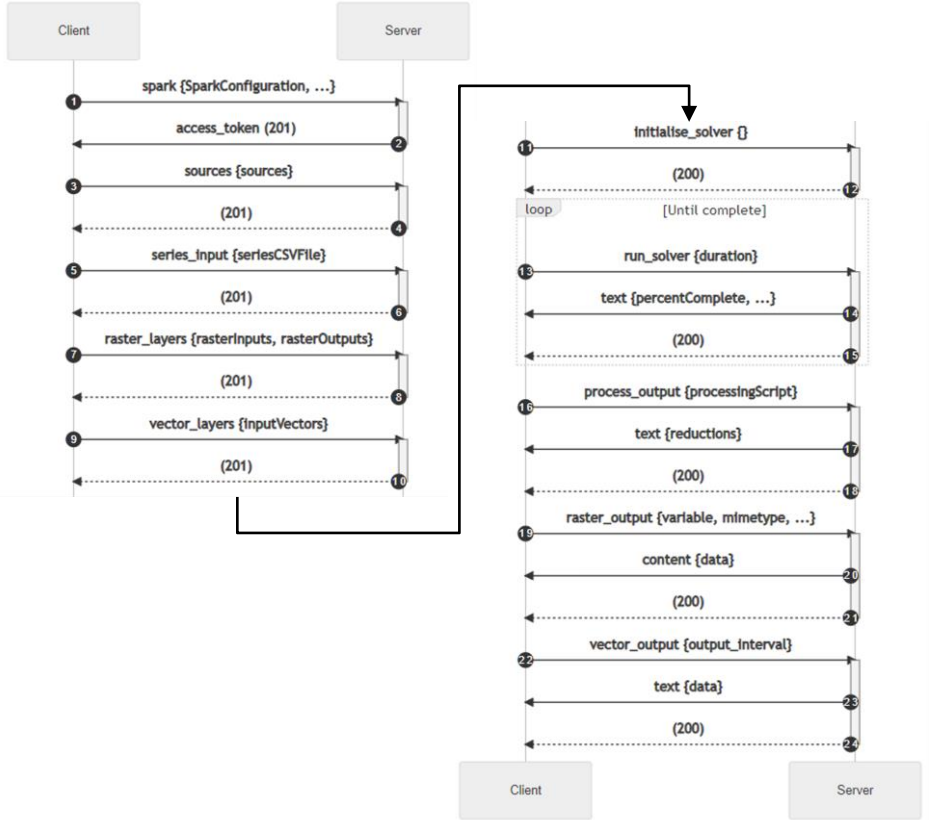
  - *Services calls from SparkWeb*
  - *Can be called directly to run simulations/serve outputs*
  - *All models sent to server*
- API calls
  - *Documentation and examples available*
  - */spark - Initialise solver*
  - */spark/sources – Set sources (geojson)*
  - */spark/initialise_solver – Initialise solver*
  - */spark/run_solver – Run solver*
  - */spark/process_output – Custom post-processing*
  - */spark/raster_output – Get gridded output (tiff/json)*
  - */spark/vector_output – Get vector output (shp/geojson)*
  - *Success codes 200/201*



SparkWeb

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  - */spark/raster_output – Get gridded output (tiff/json)*
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  - *Success codes 200/201*

```
requests.post(f"http://localhost:{port}/spark/sources", headers=headers,
json={
    "sources" : {
        "features" : [
            {
                "geometry" : {
                    "coordinates" : [ 150.342, -33.6 ],
                    "type" : "Point"
                },
                "properties" : {
                    "radius" : 120,
                    "time" : 0
                },
                "type" : "Feature"
            }
        ],
        "type" : "FeatureCollection"
    }
})
```