Spark

The 'Spark Research: A fire behaviour modelling platform' project received investment (https://doi.org/10.47486/DC004) from the Australian Research Data Commons (ARDC) and Minderoo Foundation. The ARDC is funded by the National Collaborative Research Infrastructure Strategy (NCRIS).

June 2023

Australian Research Data Commons

MINDEROO FOUNDATION

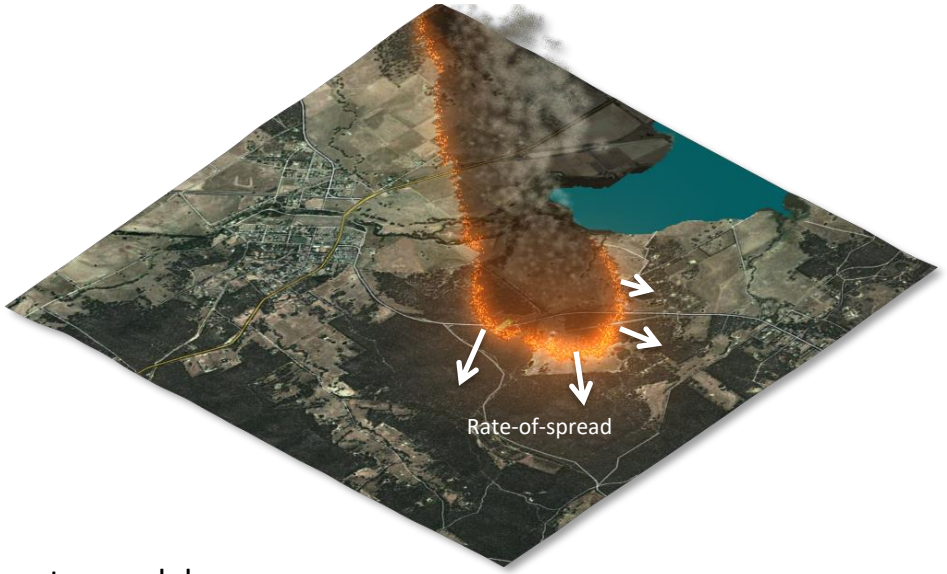
CSIRO

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

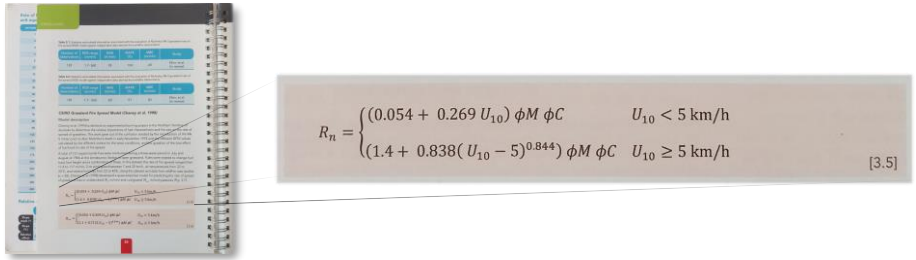
Introduction

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

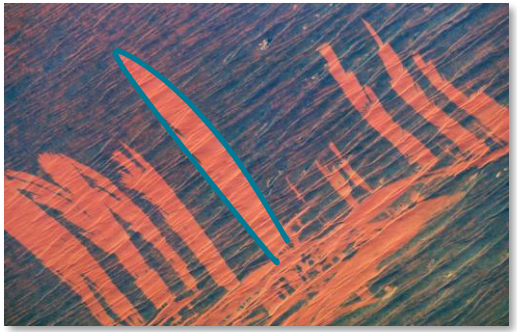


$$R_n = \begin{cases} (0.054 + 0.269\,U_{10})\,\phi M\,\phi C & U_{10} < 5\ \text{km/h} \\ (1.4 + 0.838(U_{10} - 5)^{0.844})\,\phi M\,\phi C & U_{10} \geq 5\ \text{km/h} \end{cases} \quad [3.5]$$

Need to use many different models for fire prediction

- Each model may require different data

Eucalypt fire. Source: RMIT



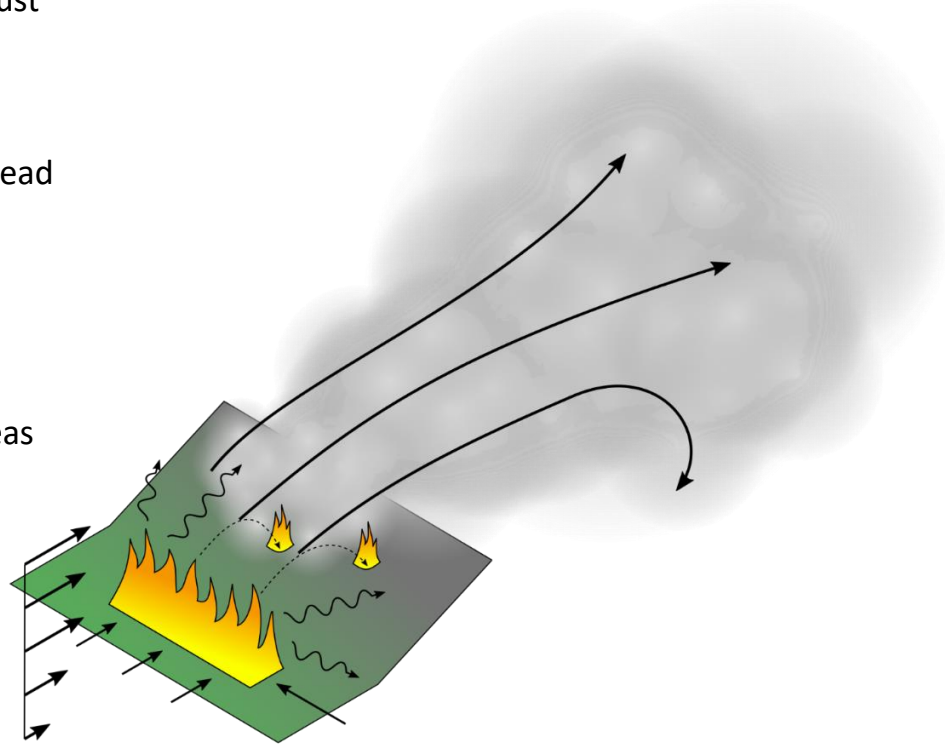
Spinifex fire. Source: NASA Earth Observatory

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

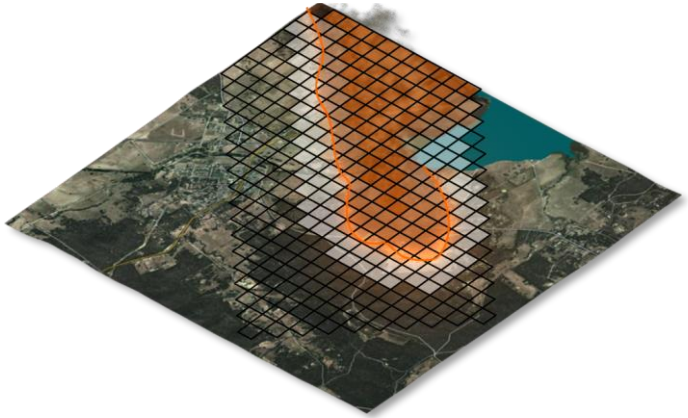
- Domain is a set of cells
- Fire spreads from cell to cell
- Extremely efficient processing
- Cell geometry affects simulation

Modelling

Spark model

Level set method:

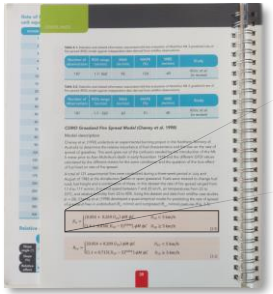
- Precise control of rate-of-spread in each cell
- Automatically handles merging fires
- Efficient and scalable on new computer hardware



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



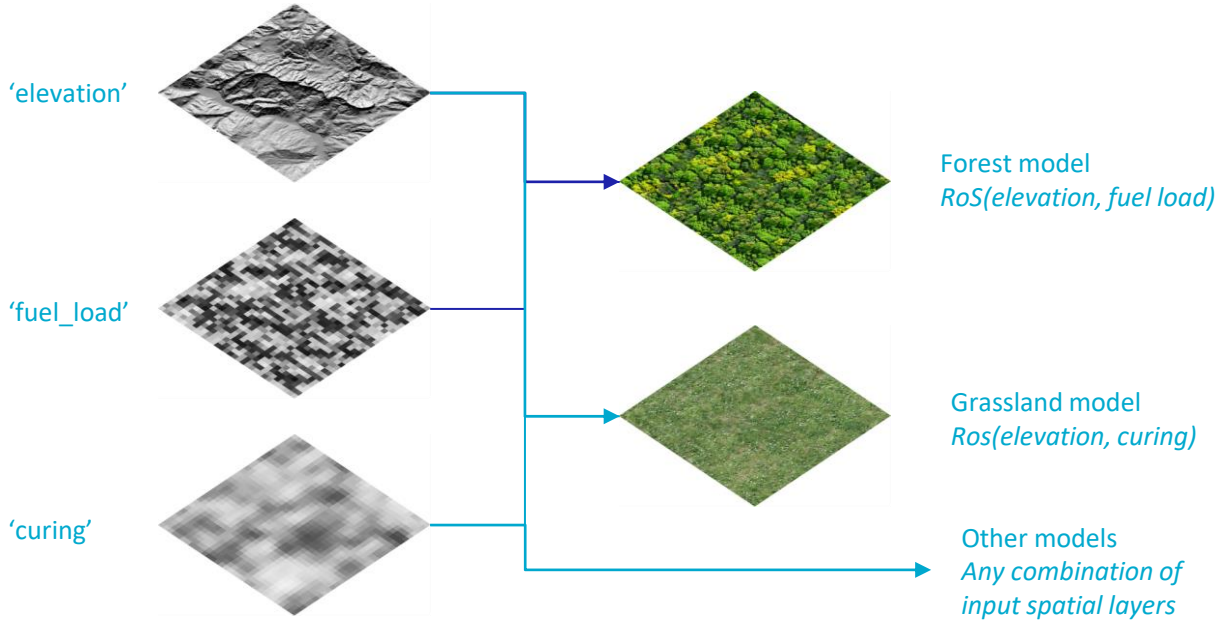
```
// Calculate spread rate from Cheney et al. (1998) (need to convert spread rate to m/s from km/hr)
if ( wind >= 5.0 )
    speed = ( 1.4 + 0.838 * pow( (wind - 5), 0.844 ) ) * moisture_coeff * curing_coeff / 3.6;
else
    speed = (0.054 + 0.269 * wind) * moisture_coeff * curing_coeff / 3.6;
```

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 – User Guide

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Australia's National Science Agency

Australian Research Data Commons

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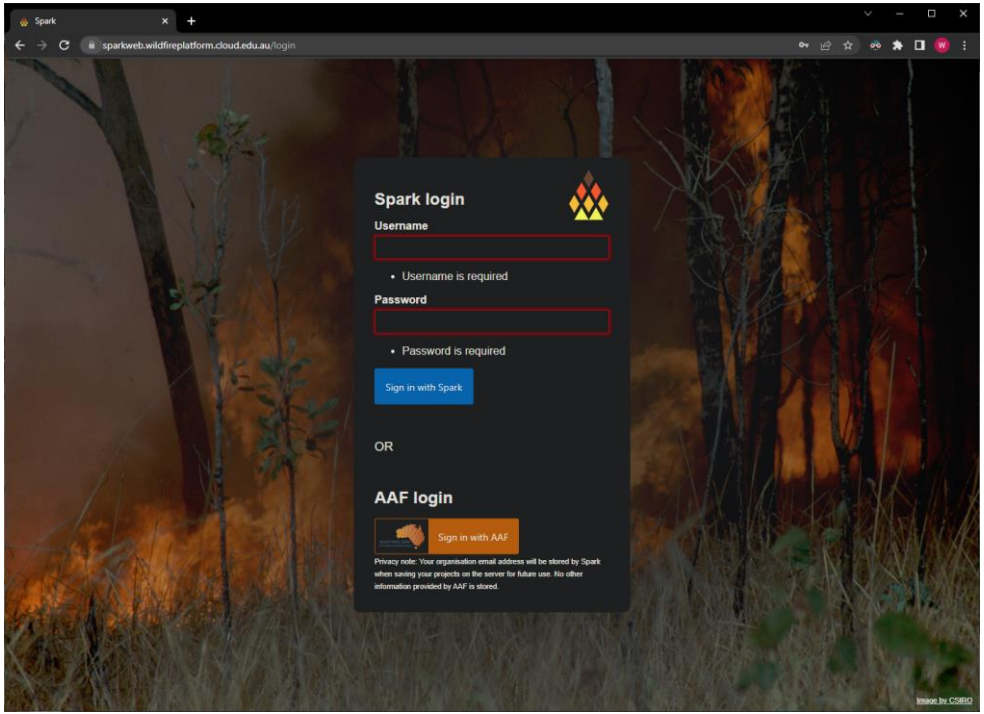
Usage

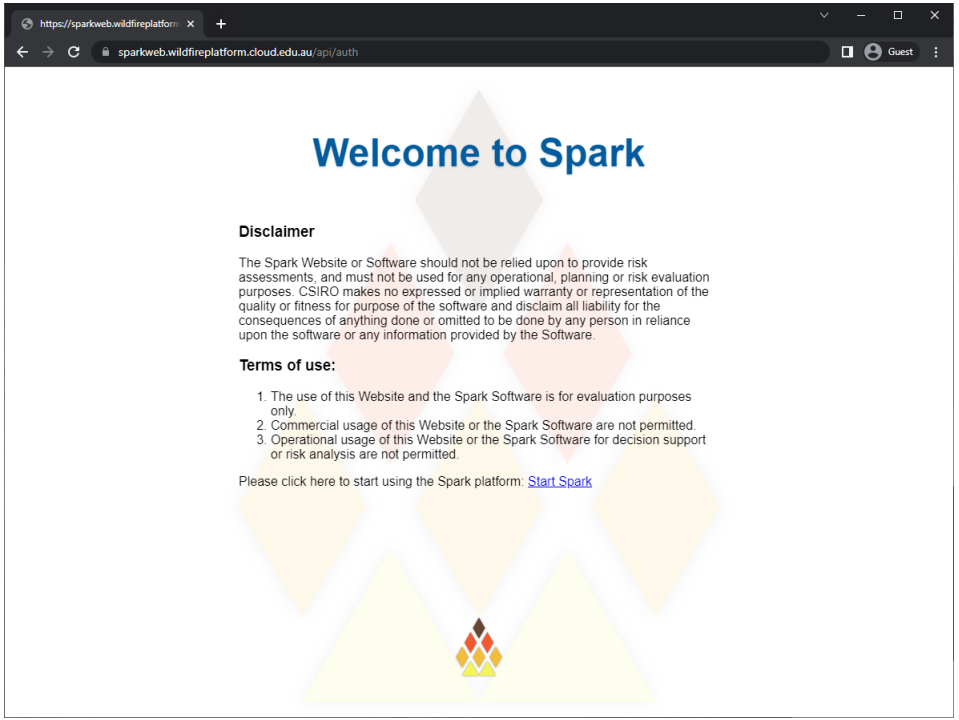
- Authentication required



SparkWeb

Usage

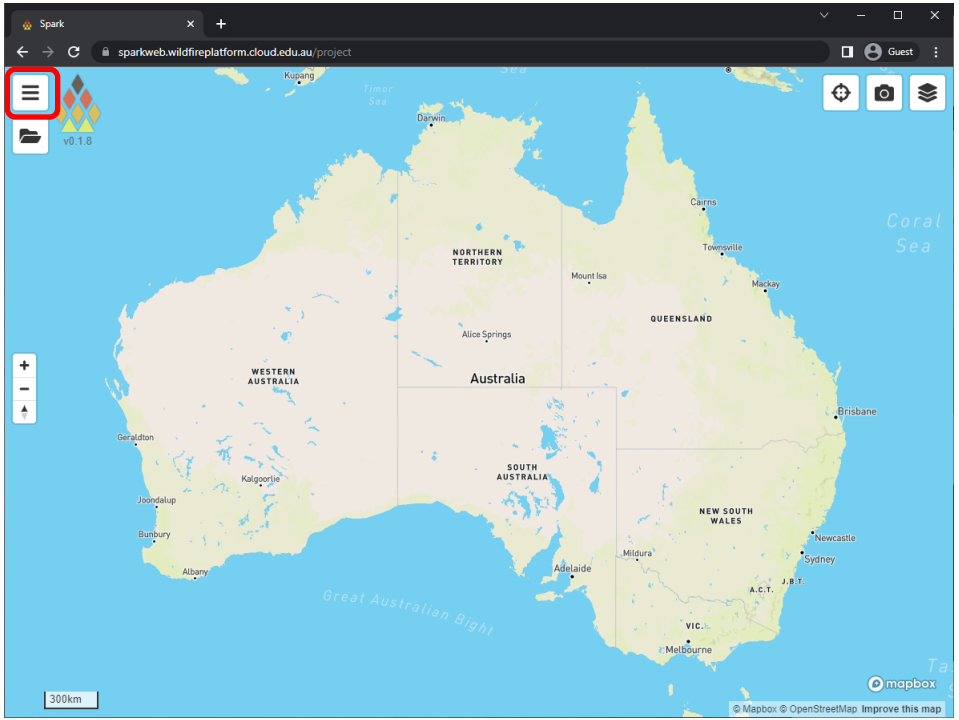
- Authentication required
- Terms of use



SparkWeb

Usage

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



SparkWeb

Usage

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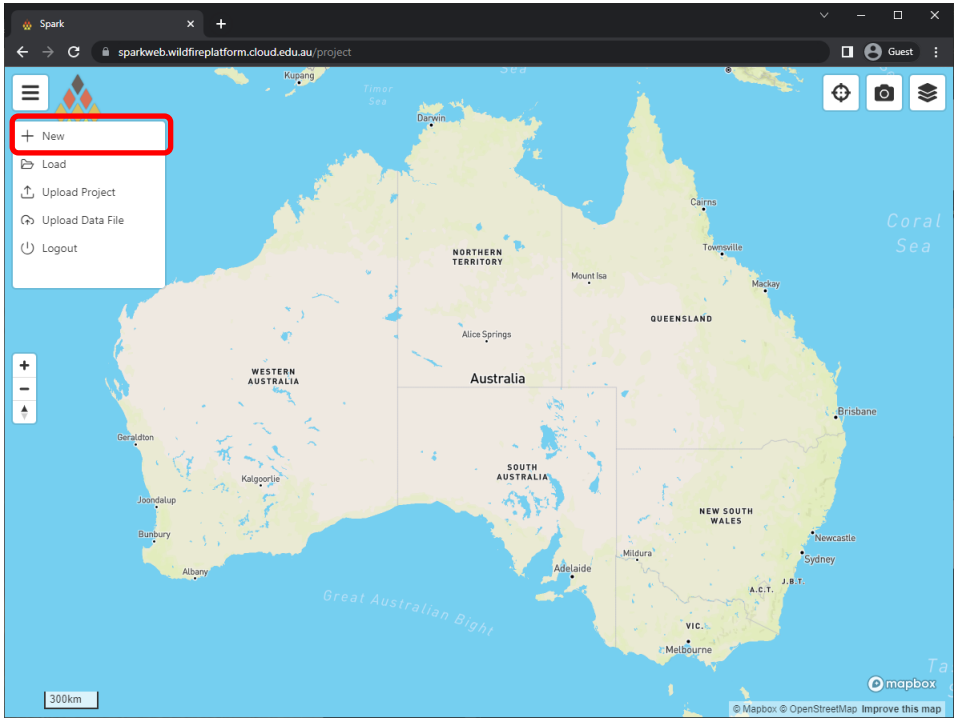
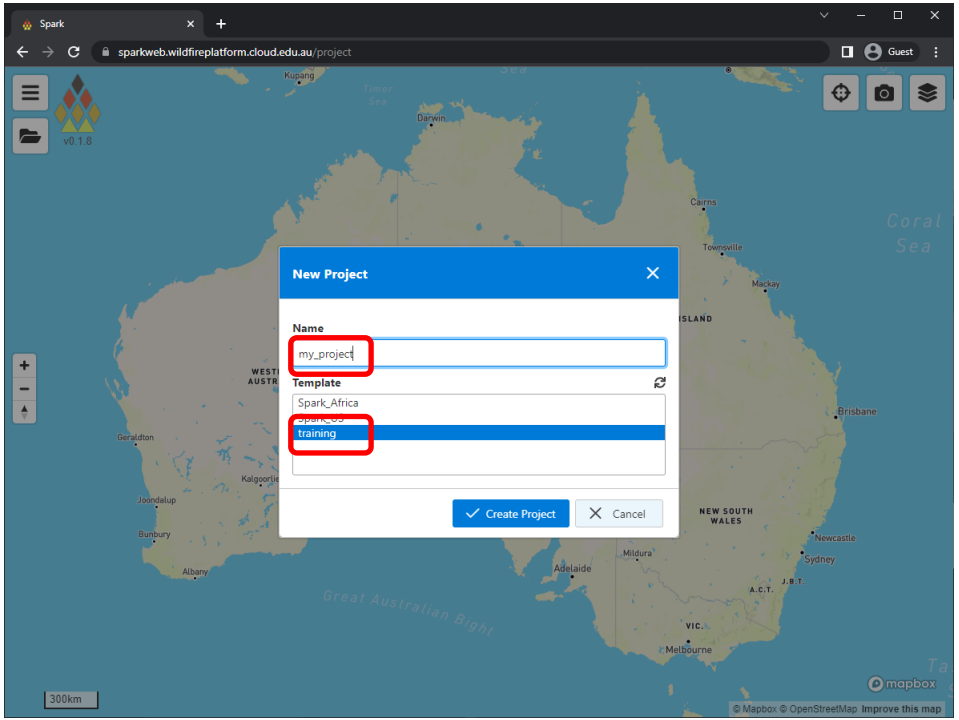
- Terms of use
- Create a new project



SparkWeb

Usage

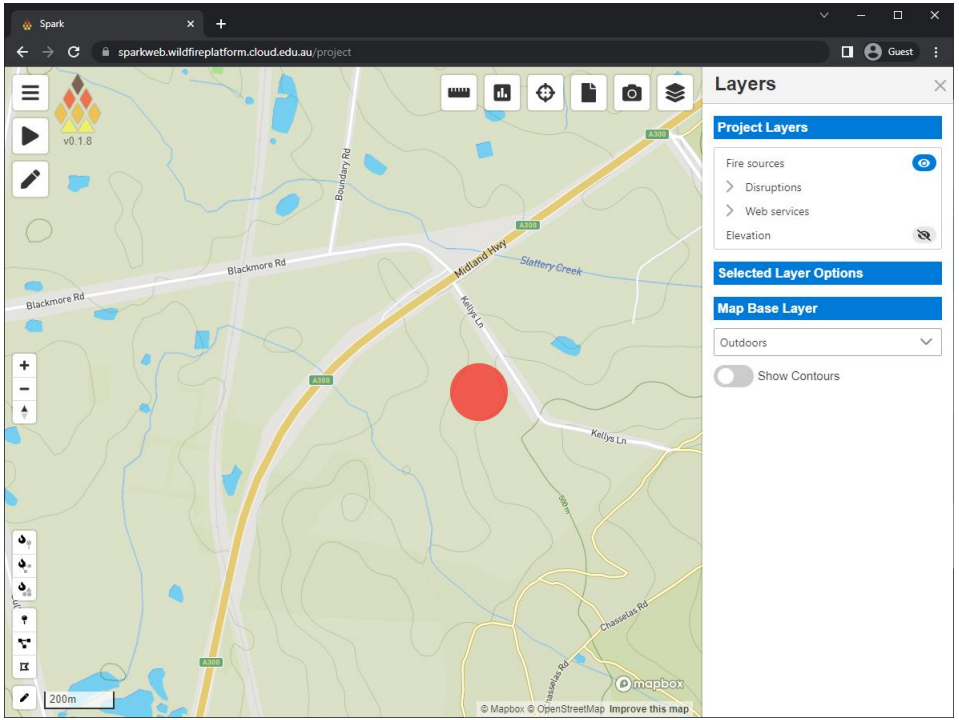
- Authentication required
- Terms of use
- Create a new project
  - *Projects must be named*
  - *Pre-populated templates*



SparkWeb

Usage

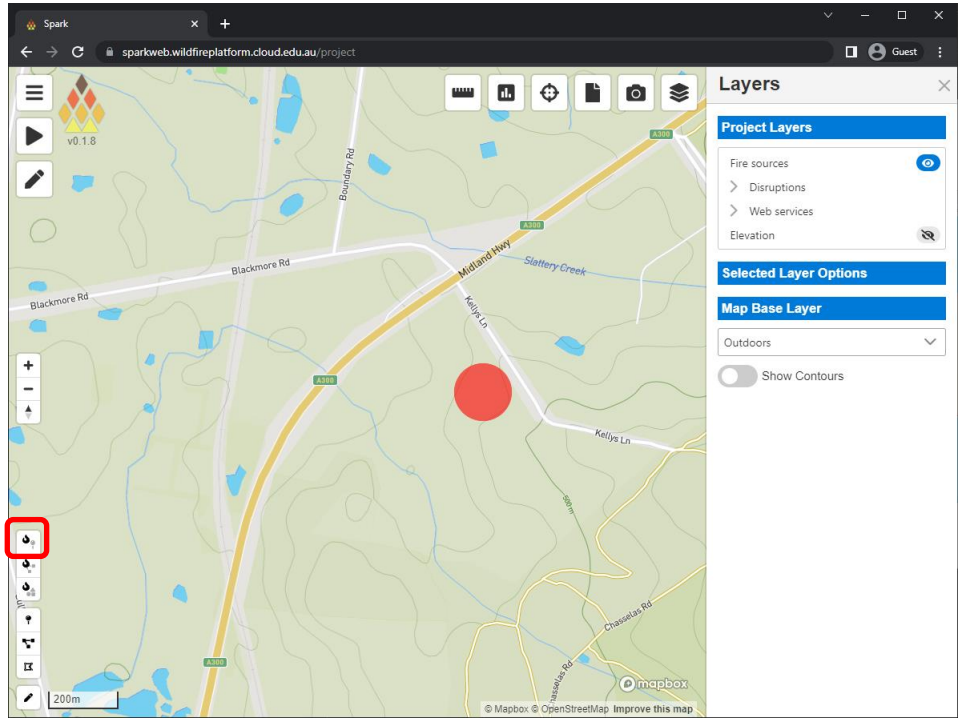
- Authentication required
- Terms of use
- Create a new project
  - *Projects must be named*
  - *Pre-populated templates*
- Layer panel on right-hand side



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 tool*



SparkWeb

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- Terms of use
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- Layer panel on right-hand side
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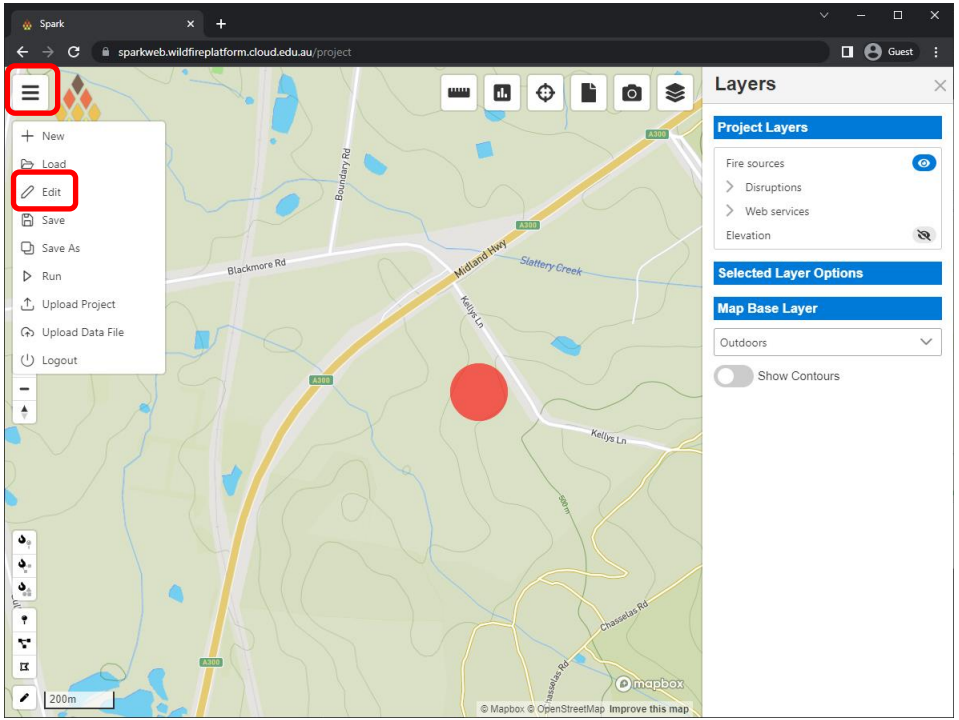
  - *Tools on lower left*
  - *Point tool*
- Basic simulation parameters



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  - *Projects must be named*
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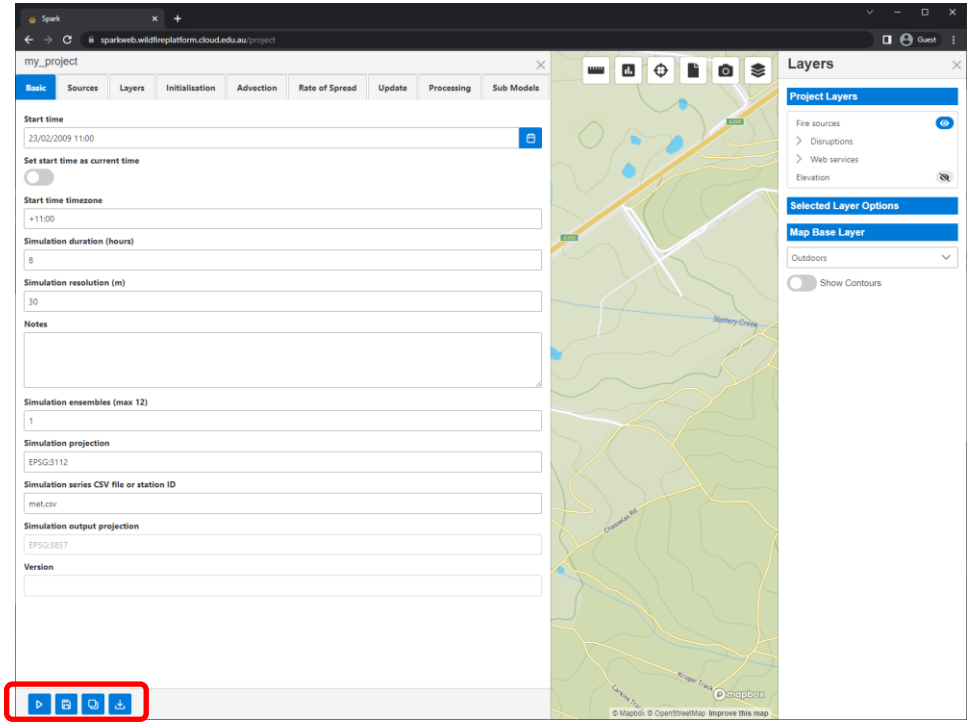
- Layer panel on right-hand side
- Fire input conditions
  - *Tools on lower left*
  - *Point tool*
- Basic simulation parameters
  - *Start date and time*
  - *Time zone*
  - *Simulation duration*
  - *Simulation resolution*
- Project controls
  - *Run*
  - *Save*
  - *Download*



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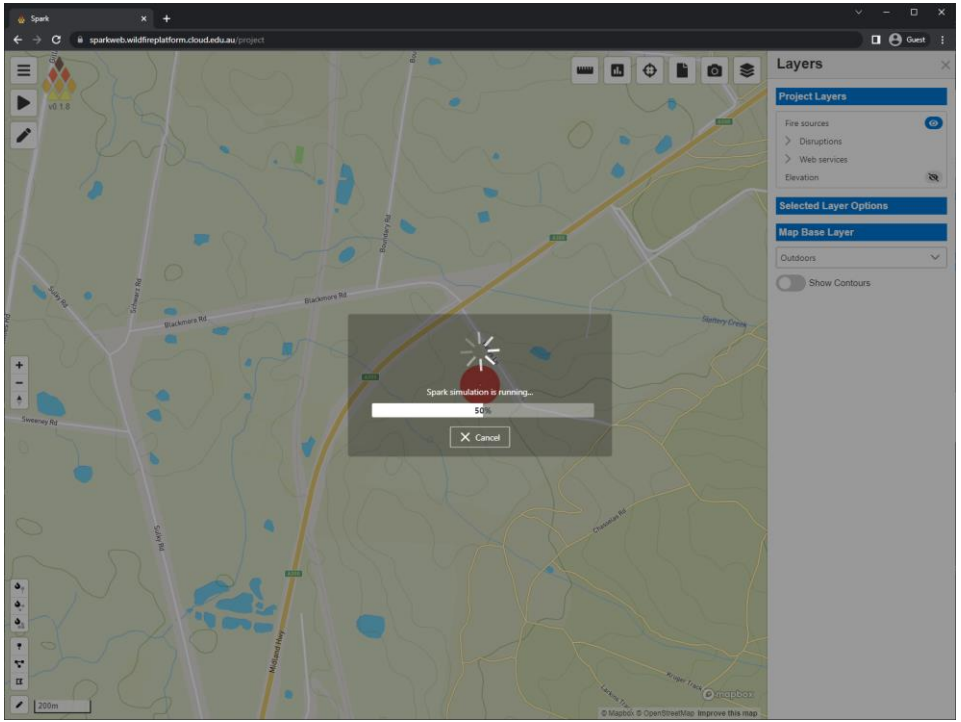
- Progress
  - *Any errors reported at this stage*



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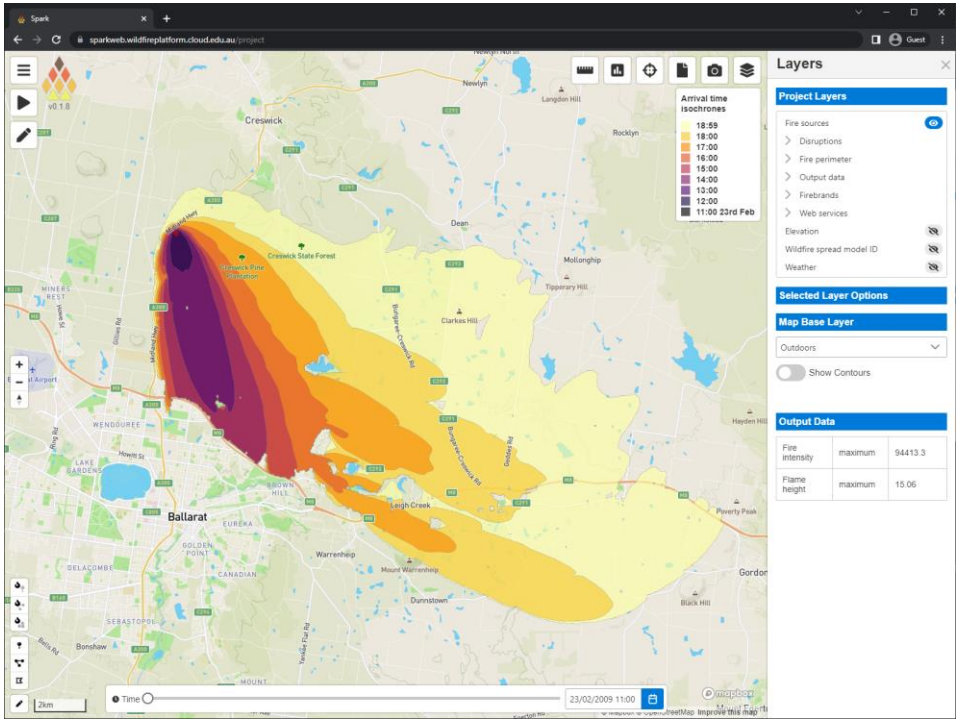
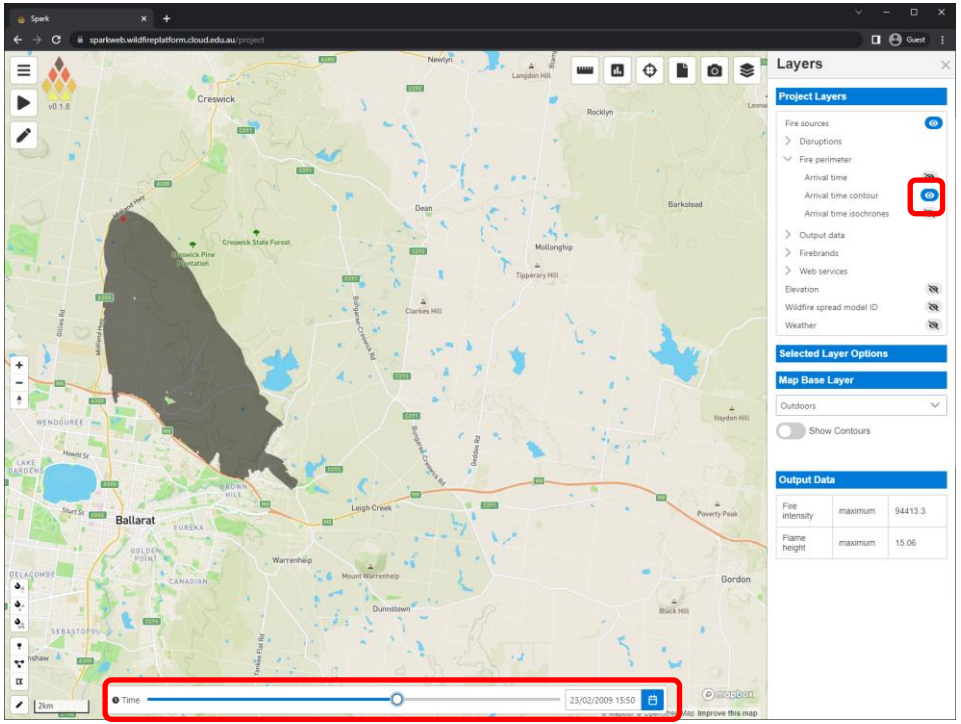
  - *Simulation duration*
  - *Simulation resolution*
- Project controls
  - *Run*
  - *Save*
  - *Download*
- Progress
  - *Any errors reported at this stage*
- Output of fire simulation
  - *Colours represent hourly progress*



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
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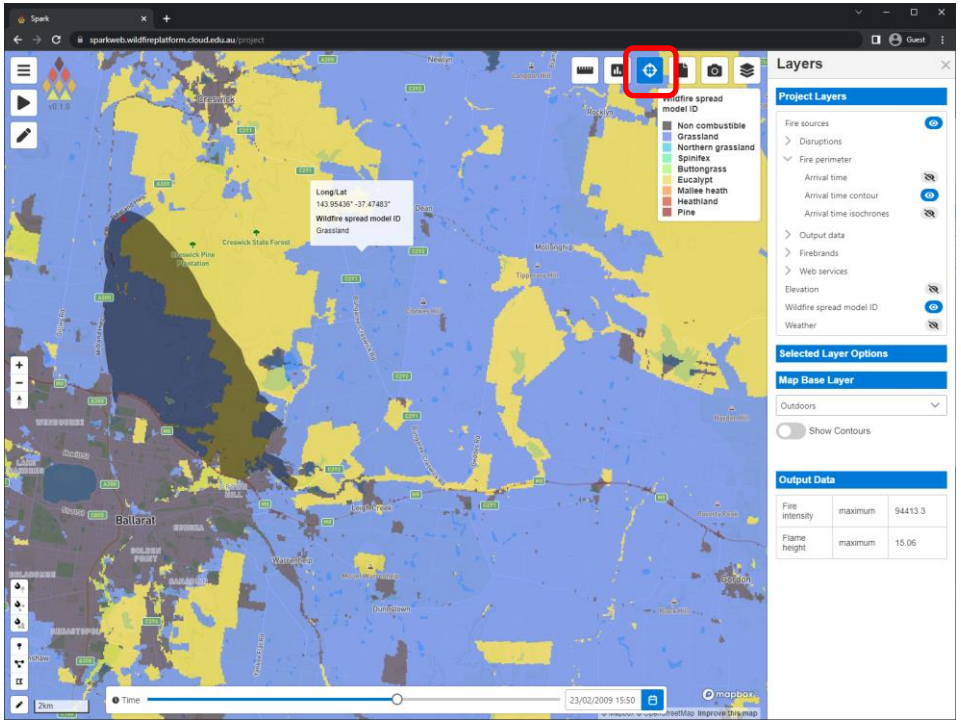
- Shaded fire contour
  - *Dynamic outline based on time slider*
- Wildfire model layer
  - *Cell evaluation using inspection tool*
  - *Current value of all layers under mouse*



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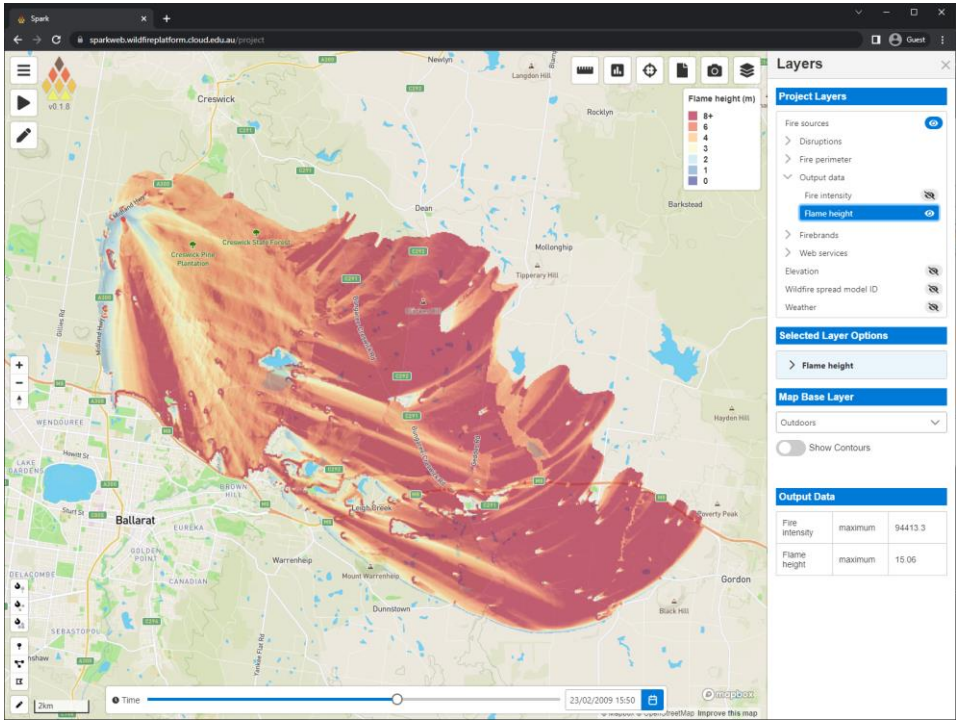
- Flame height layer



SparkWeb

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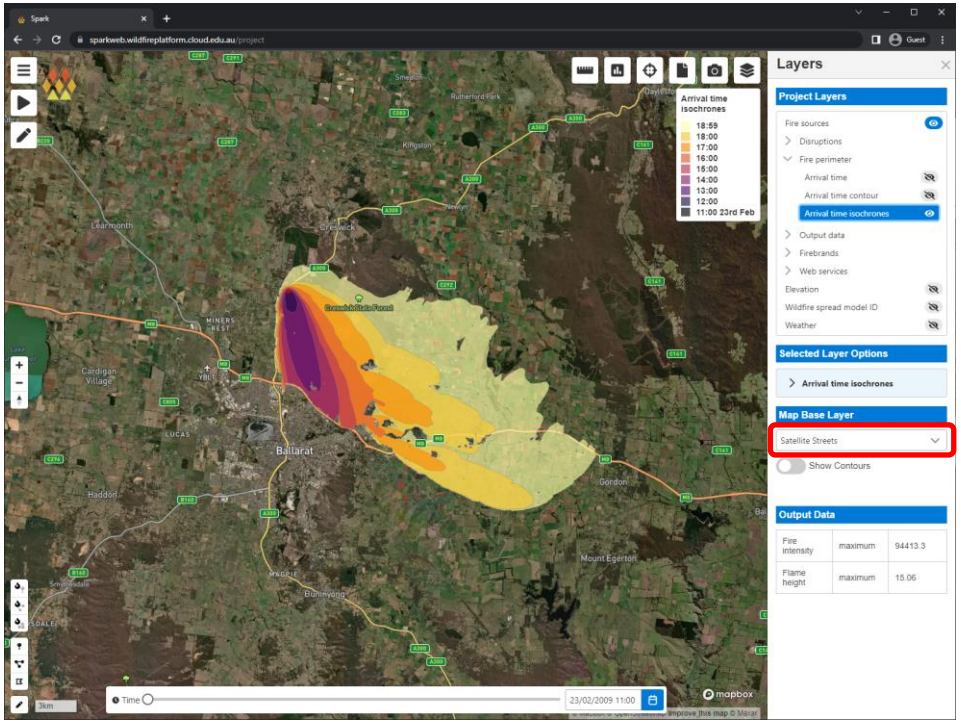
  - *Cell evaluation using inspection tool*
  - *Current value of all layers under mouse*
- Flame height layer
- Base map
  - *Various base map options*



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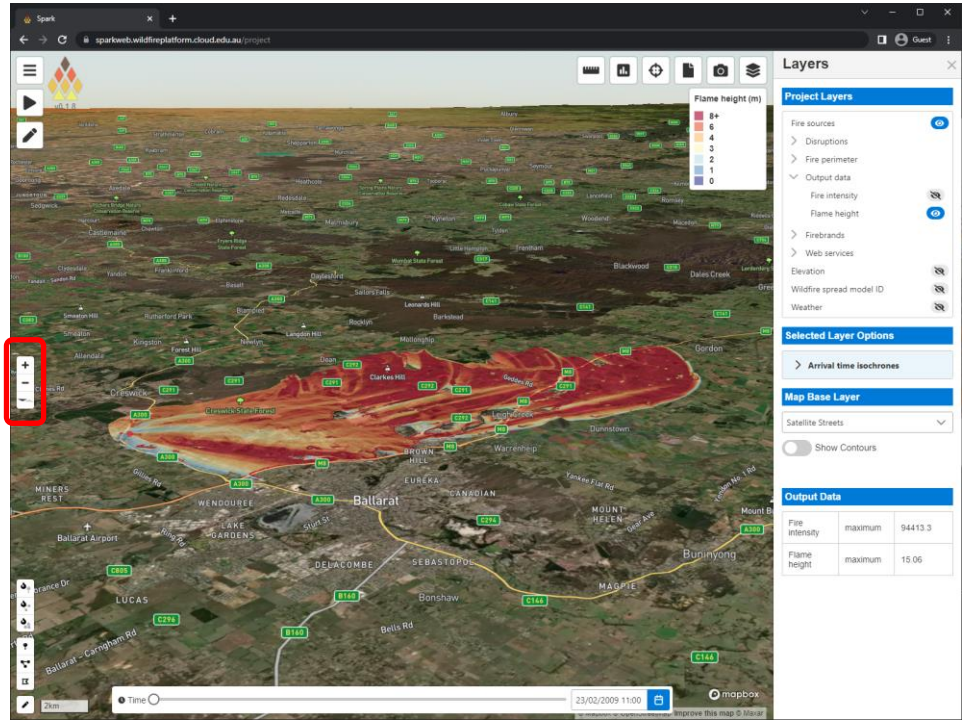
- Base map
  - *Various base map options*
- 3D view
  - *Right mouse or ctrl+left mouse to rotate view*
  - *Mousewheel to zoom*
  - *View reset using compass button*



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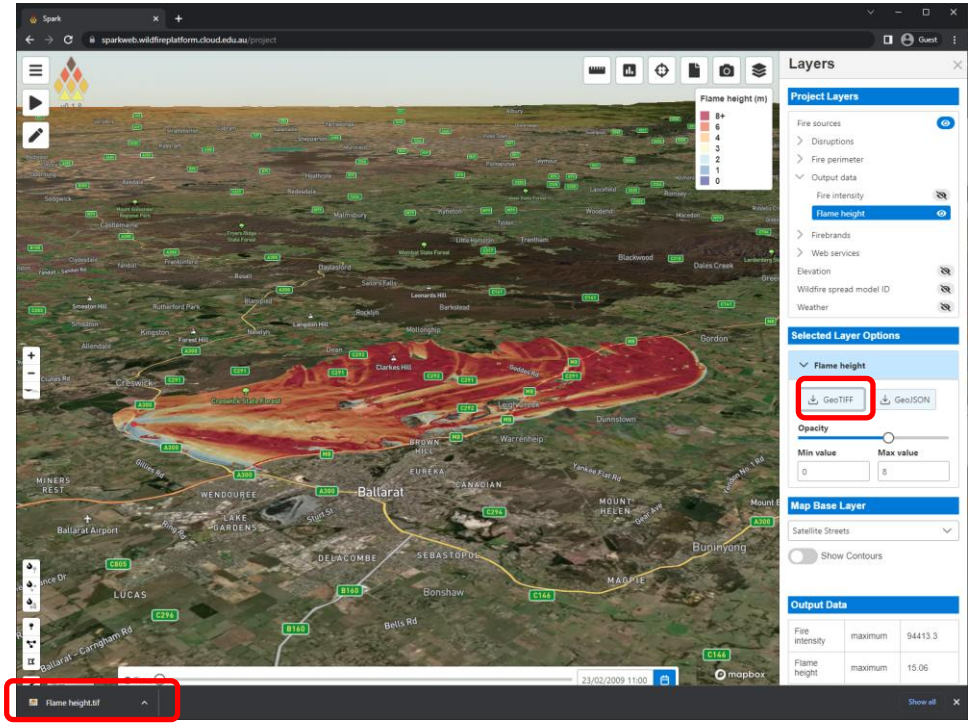
- Layer options
  - *Layer download buttons*
  - *Opacity slider*
  - *Colour map*
  - *Colour range*
- Layer download



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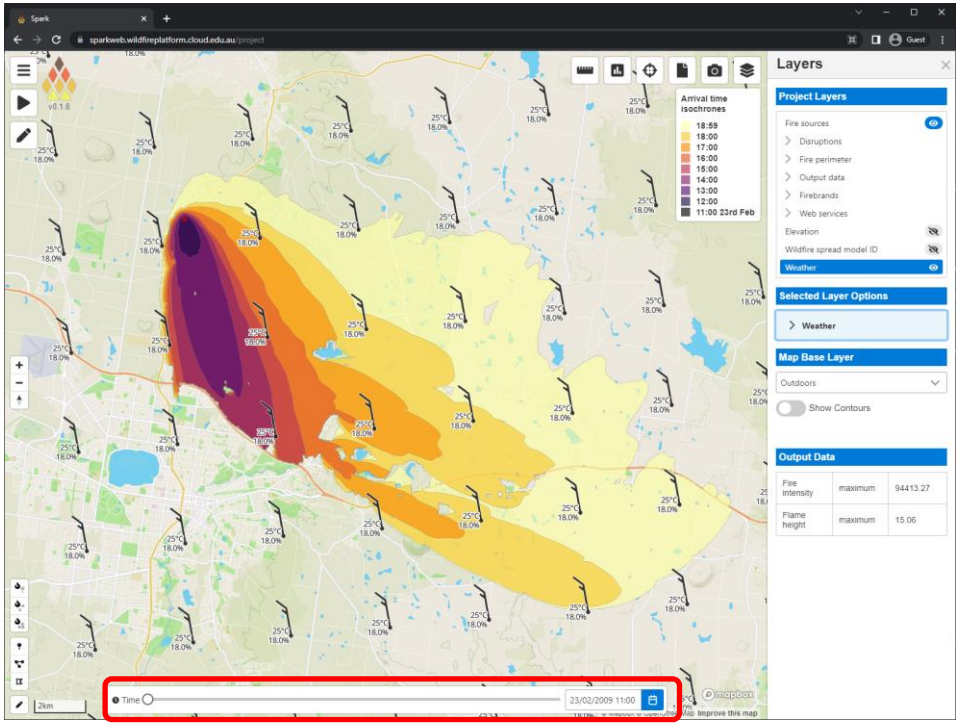
- Layer options
  - *Layer download buttons*
  - *Opacity slider*
  - *Colour map*
  - *Colour range*
- Layer download
- Weather
  - *Changes with time slider*



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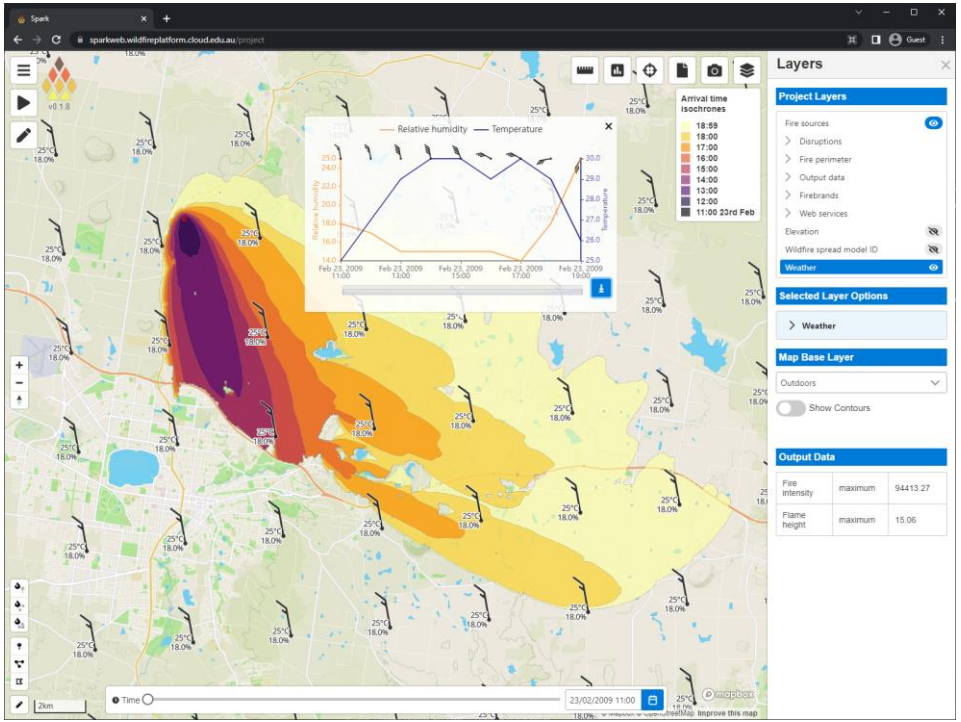
  - *Colour map*
  - *Colour range*
- Layer download
- Weather
  - *Changes with time slider*
  - *Shows time series chart when icon is clicked*



SparkWeb

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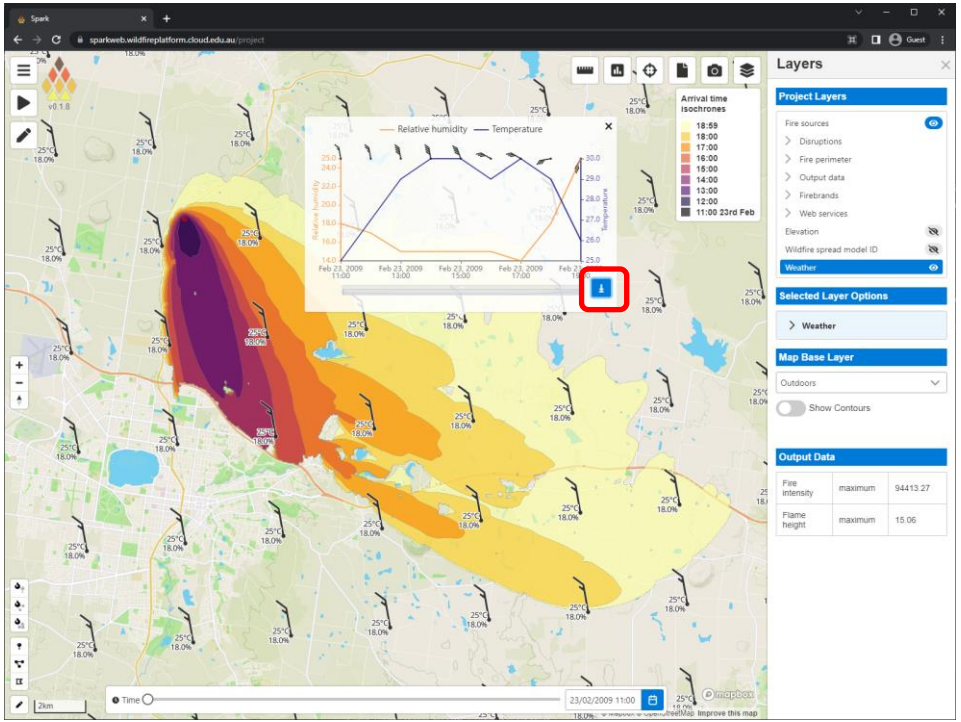
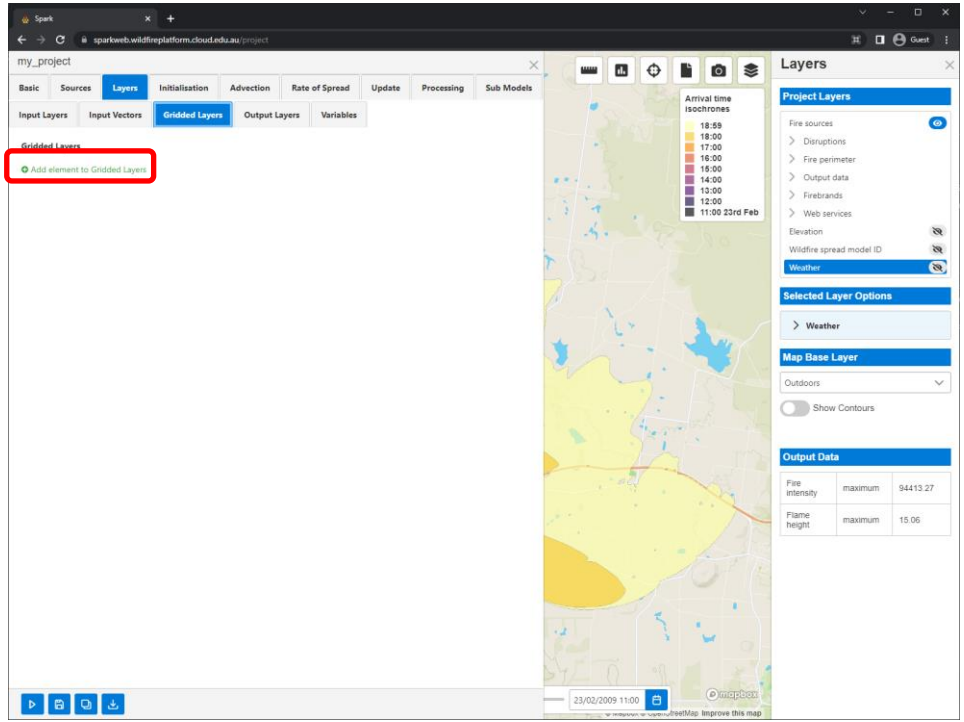
- Layer options
  - *Layer download buttons*
  - *Opacity slider*
  - *Colour map*
  - *Colour range*
- Layer download
- Weather
  - *Changes with time slider*
  - *Shows time series chart when icon is clicked*
  - *Can be downloaded as a csv*



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*

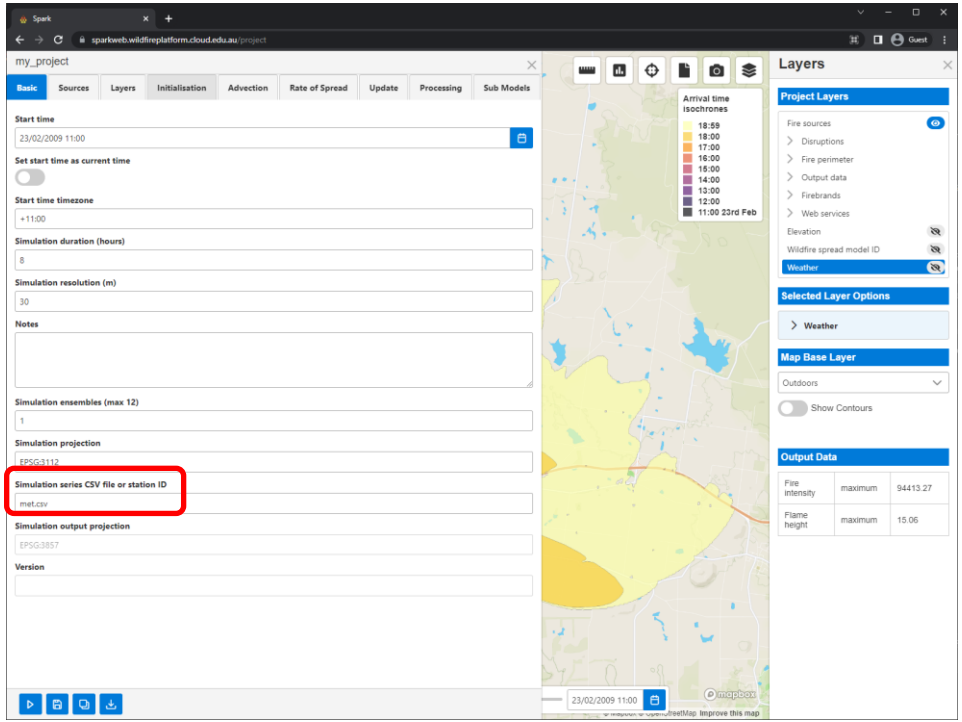


SparkWeb

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:*

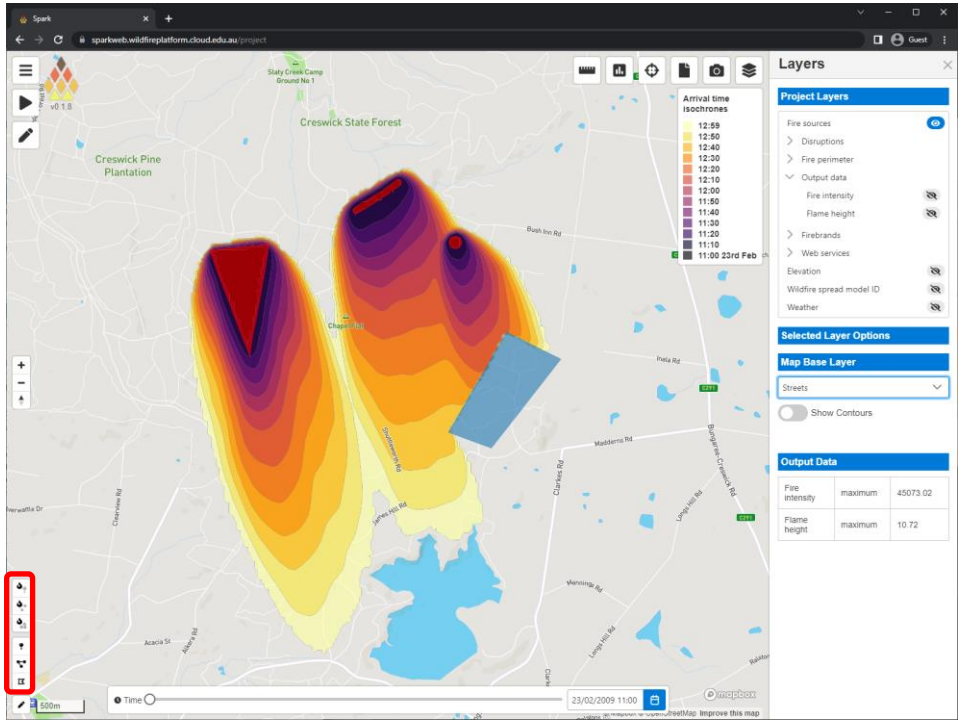
date	relative_humidity	temperature	wind_direction	wind_magnitude
2009-02-23T11:00:00+11:00	18	25	350	15
2009-02-23T12:00:00+11:00	17	27	350	25
2009-02-23T13:00:00+11:00	15	29	350	39
2009-02-23T14:00:00+11:00	15	30	350	39
2009-02-23T15:00:00+11:00	15	30	340	39
2009-02-23T16:00:00+11:00	15	29	300	30
2009-02-23T17:00:00+11:00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

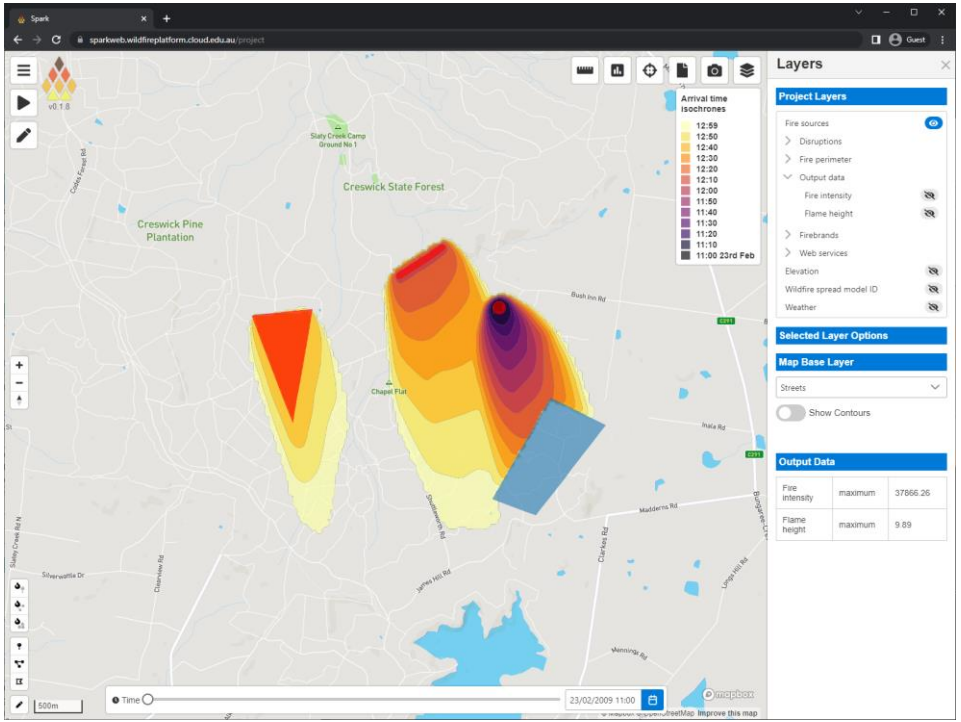
- Input tools
  - *Point fire creation*
  - *Line fire creation*
  - *Polygon fire creation*
  - *Mask (un-burnable) creation*



SparkWeb

Advanced usage

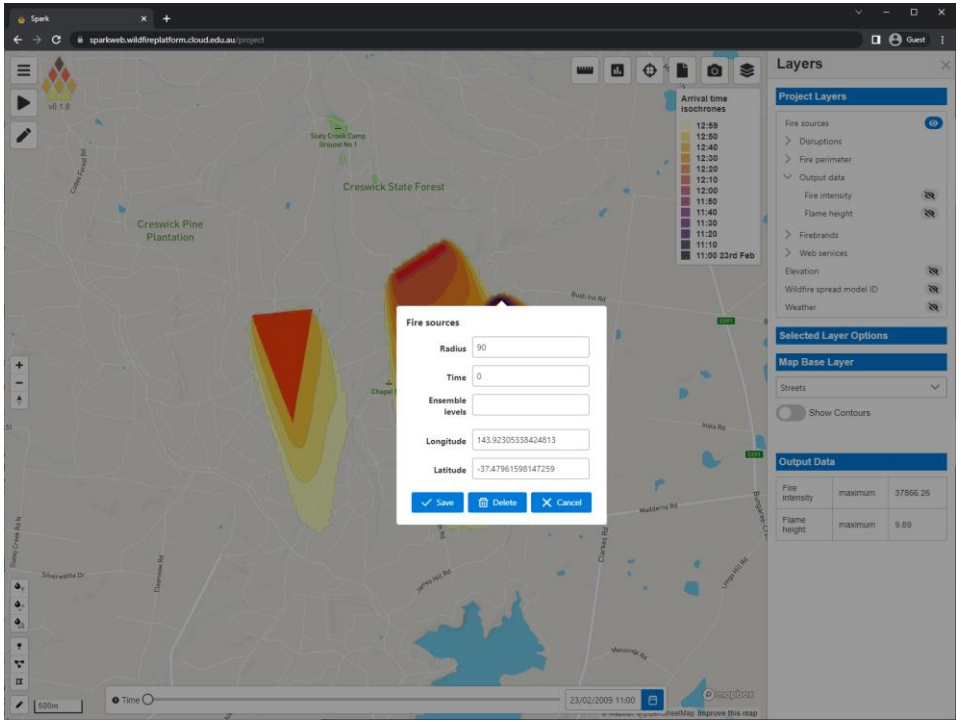
- Input tools
  - *Point fire creation*
  - *Line fire creation*
  - *Polygon fire creation*
  - *Mask (un-burnable) creation*
- Multiple geometries
  - *Different start times*



SparkWeb

Advanced usage

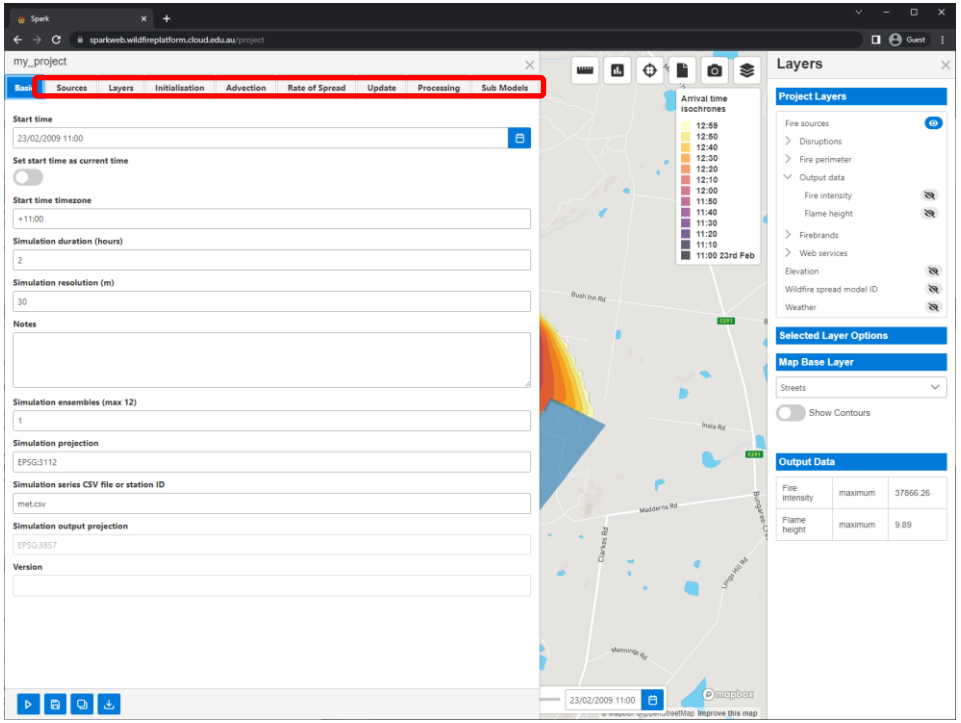
- Input tools
  - *Point fire creation*
  - *Line fire creation*
  - *Polygon fire creation*
  - *Mask (un-burnable) creation*
- Multiple geometries
  - *Different start times*
  - *Left-click to configure*
  - *Set geometry properties*
  - *Set ignition time*
  - *Set position*



SparkWeb

Advanced usage

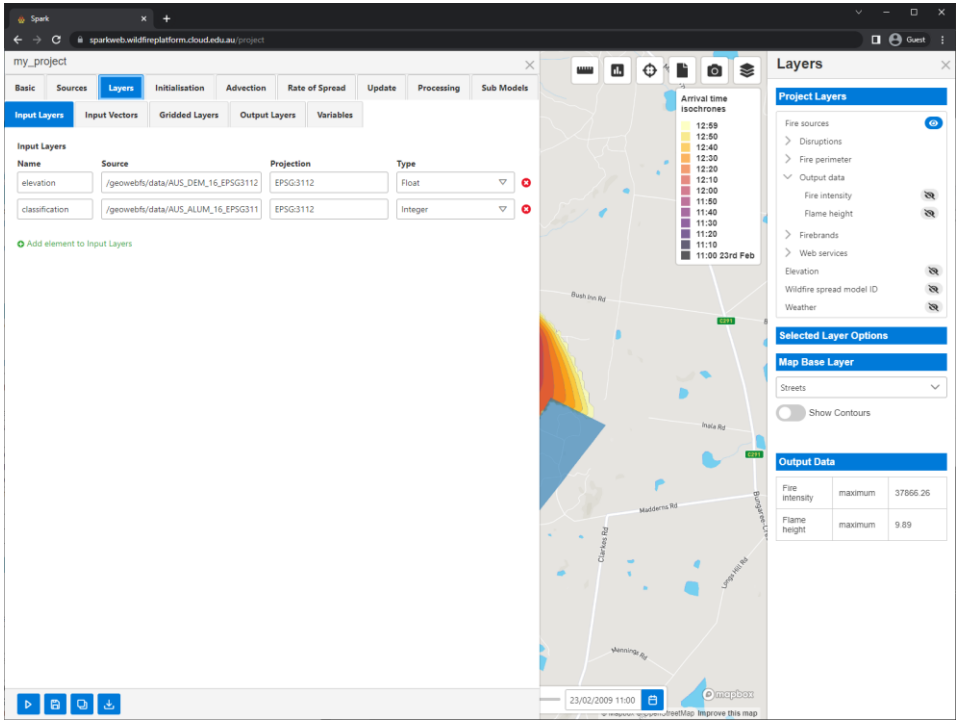
- Advanced options
  - *All layers and options available*



SparkWeb

Advanced usage

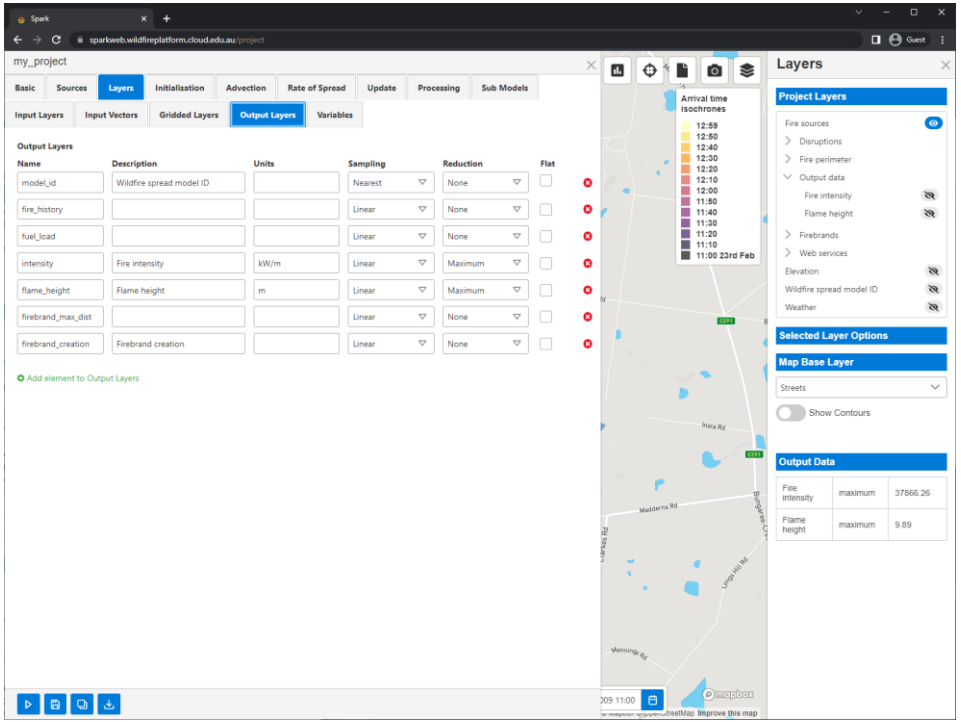
- Advanced options
  - *All layers and options available*
- Layers



SparkWeb

Advanced usage

- Advanced options
  - *All layers and options available*
- Layers
  - *Vector layers*
  - *Gridded weather layers (NetCDF)*
  - *Output layers, any with descriptions are visualised*



SparkWeb

Advanced usage

- Advanced options
  - *All layers and options available*
- Layers
  - *Vector layers*
  - *Gridded weather layers (NetCDF)*
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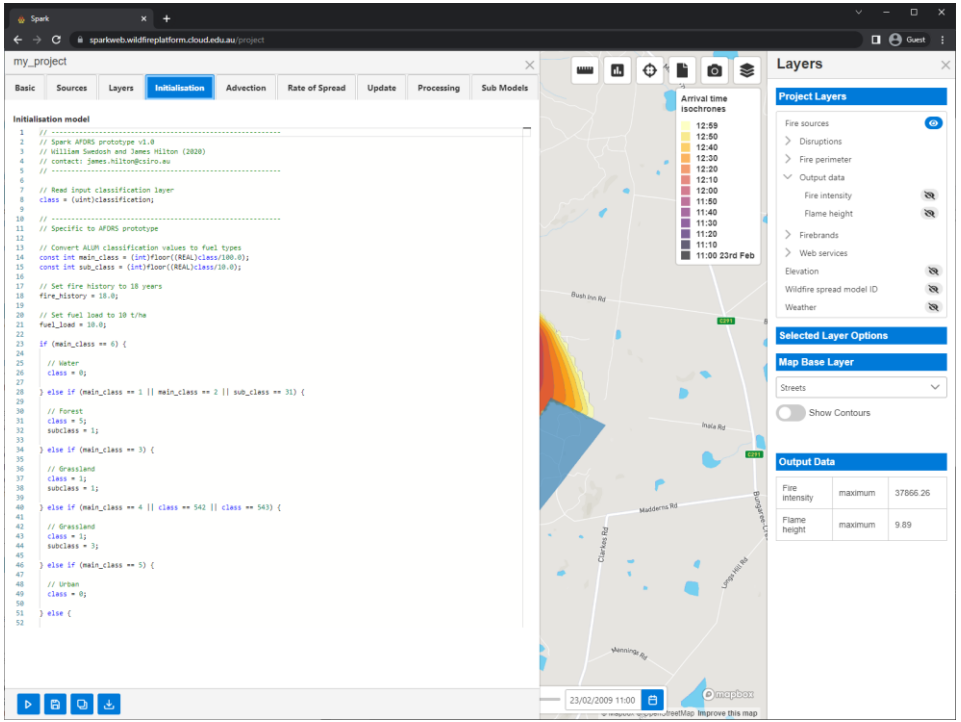
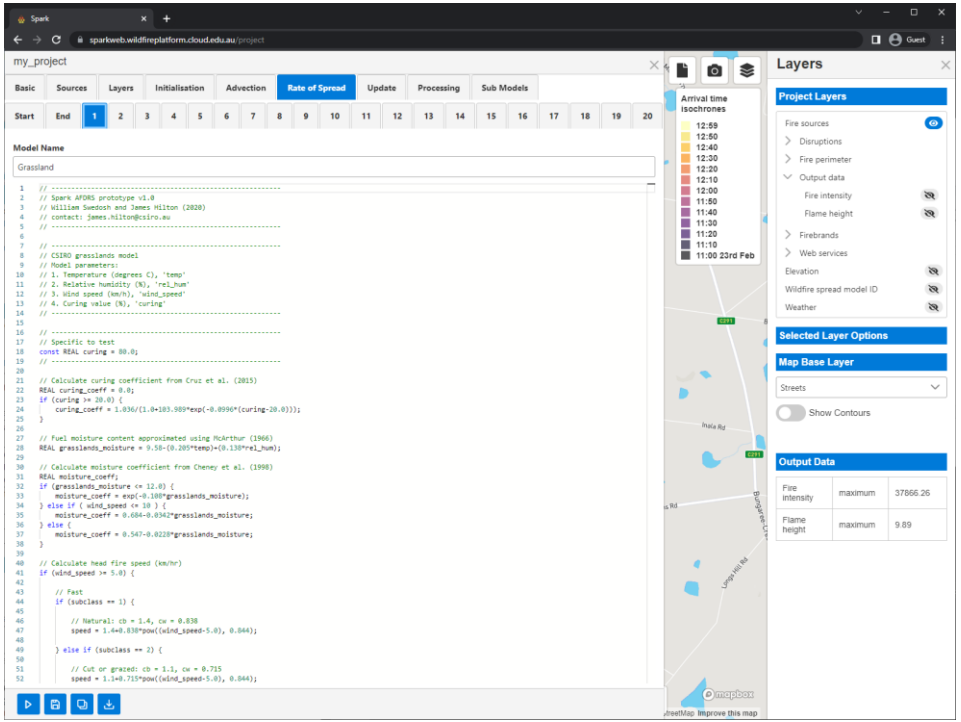
- Models
  - *Initialisation, run once per cell*



SparkWeb

Advanced usage

- Advanced options
  - *All layers and options available*
- Layers
  - *Vector layers*
  - *Gridded weather layers (NetCDF)*
  - *Output layers, any with descriptions are visualised*
- Models
  - *Initialisation, run once per cell*
  - *Advection, used to modify wind field*
  - *Rate-of-spread, run to determine outward speed*



SparkWeb

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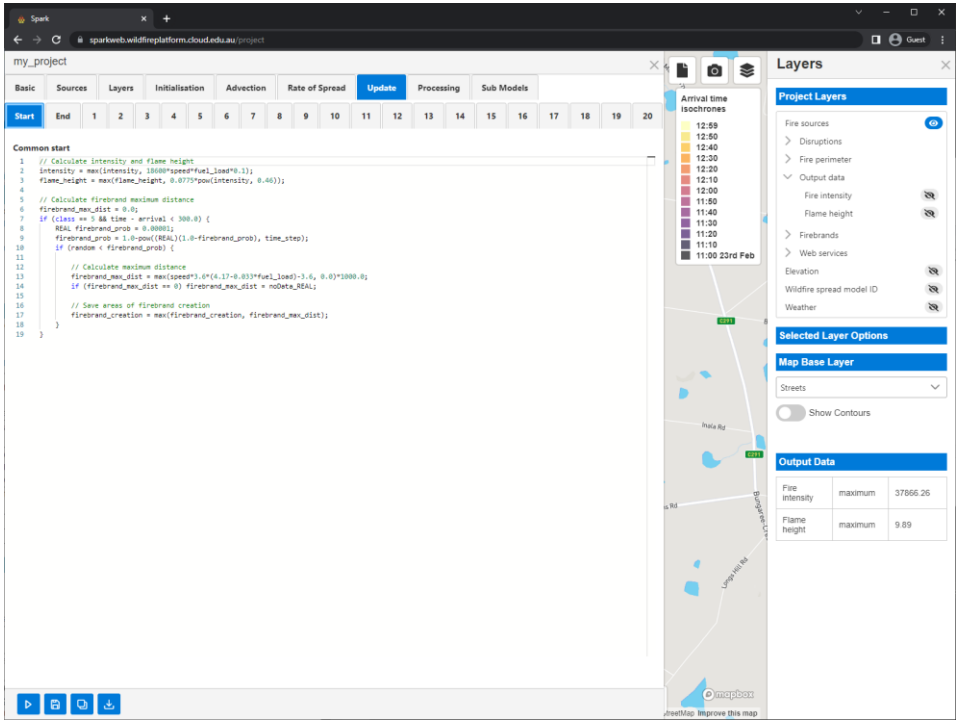
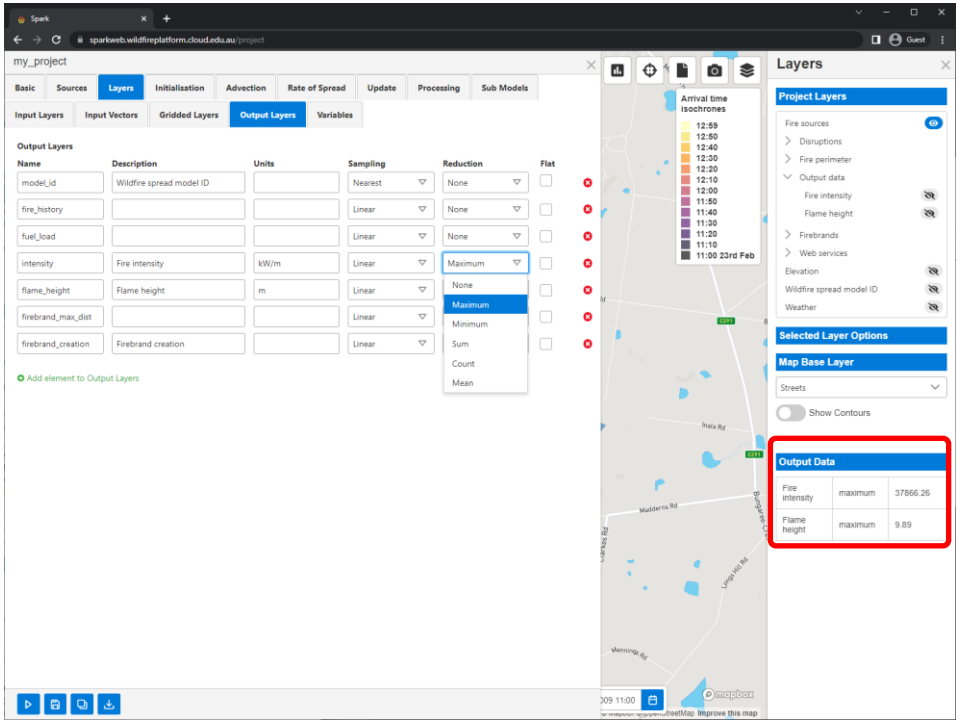
  - *All layers and options available*
- Layers
  - *Vector layers*
  - *Gridded weather layers (NetCDF)*
  - *Output layers, any with descriptions are visualised*
- Models
  - *Initialisation, run once per cell*
  - *Advection, used to modify wind field*
  - *Rate-of-spread, run to determine outward speed*
  - *Update, run within burnt regions*



SparkWeb

Advanced usage

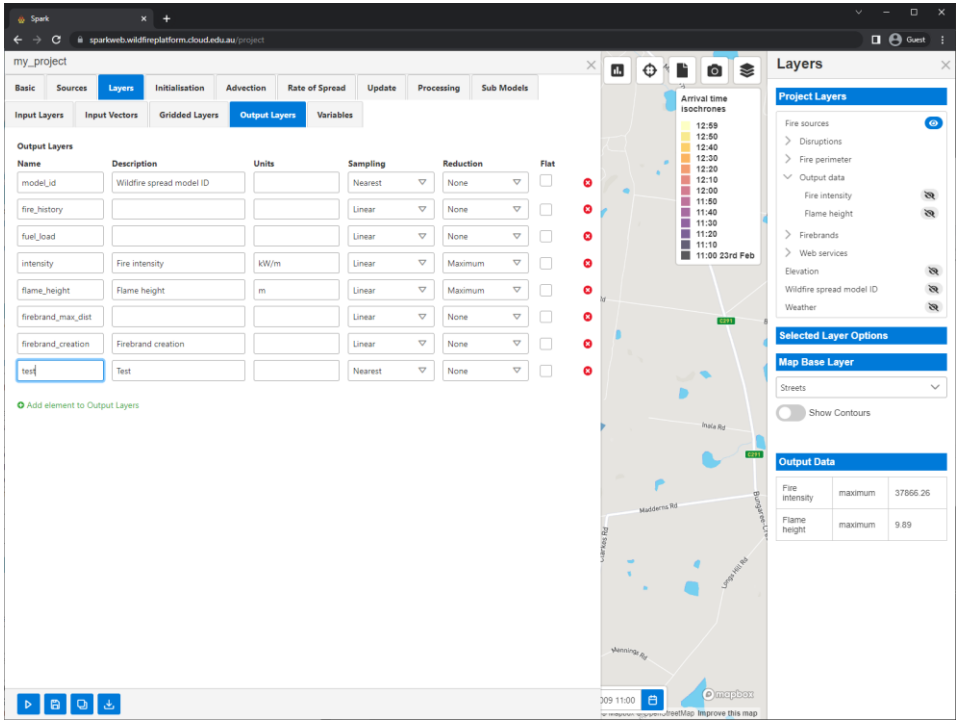
- Advanced options
  - *All layers and options available*
- Layers
  - *Vector layers*
  - *Gridded weather layers (NetCDF)*
  - *Output layers, any with descriptions are visualised*
- Models
  - *Initialisation, run once per cell*
  - *Advection, used to modify wind field*
  - *Rate-of-spread, run to determine outward speed*
  - *Update, run within burnt regions*
- Reductions
  - *Reduces output to single value*
  - *Set per-layer*
  - *Value shown in summary table*



SparkWeb

Advanced usage

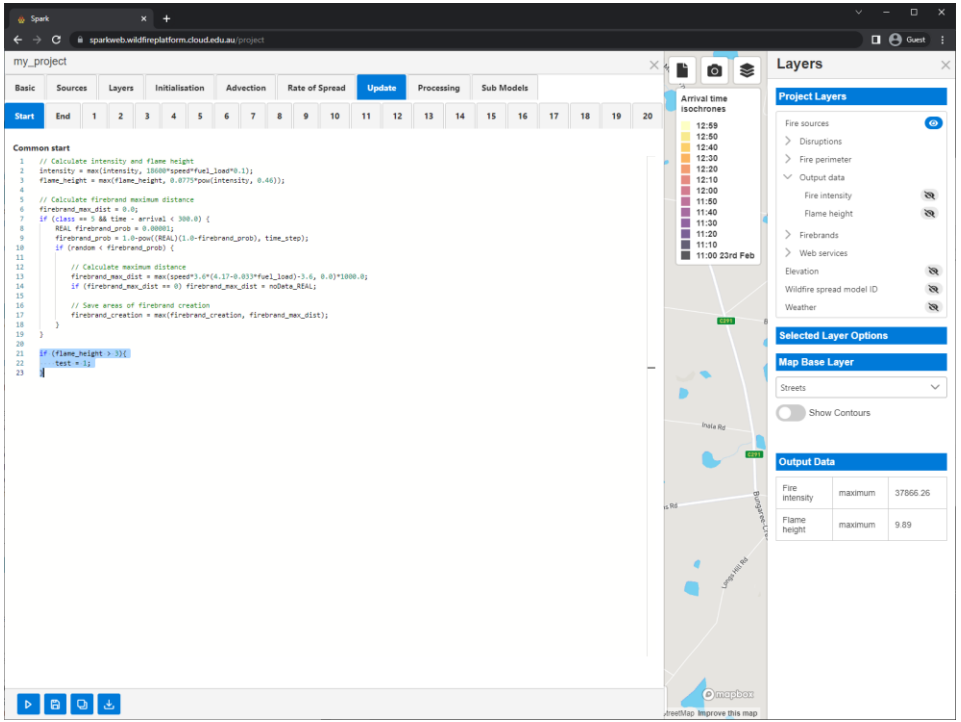
- Layer creation
  - *Any number can be created*
  - *Name available in model scripts for reading/writing*
  - *Must have description to be visualised*
  - *Example ‘test’ layer created called ‘Test’*



SparkWeb

Advanced usage

- 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’*
- Scripting
  - *Layer is written in update model*
  - *Anywhere where flame height > 3 test is 1*
  - *Elsewhere test is null*



SparkWeb

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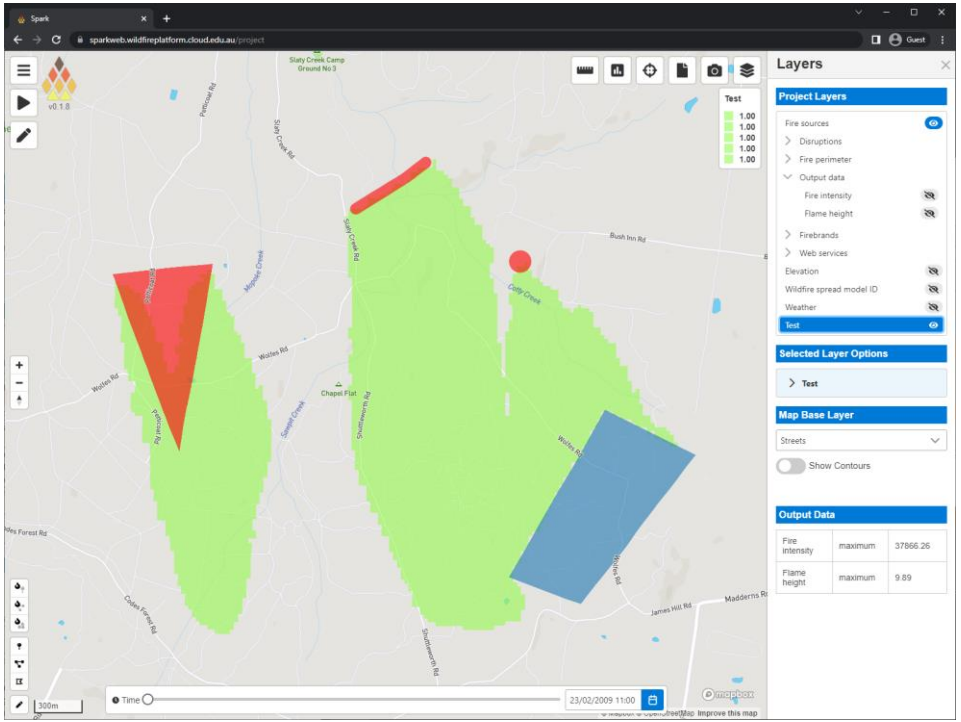
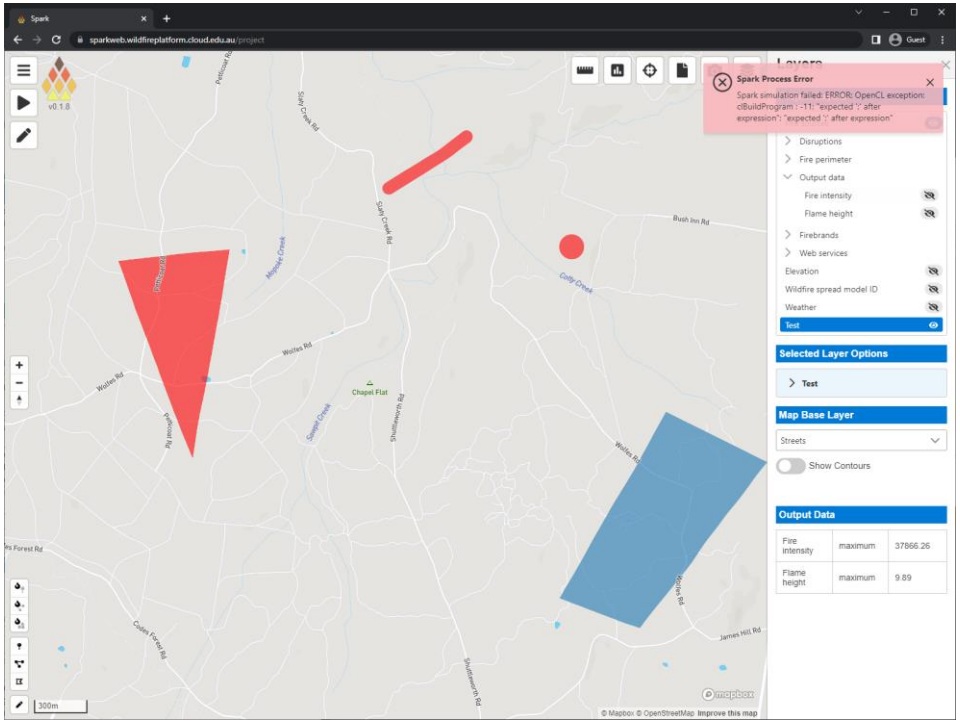
  - *Elsewhere test is null*
- Visualisation
  - *Data from ‘Test’ shown in green after simulation is run again*



SparkWeb

Advanced usage

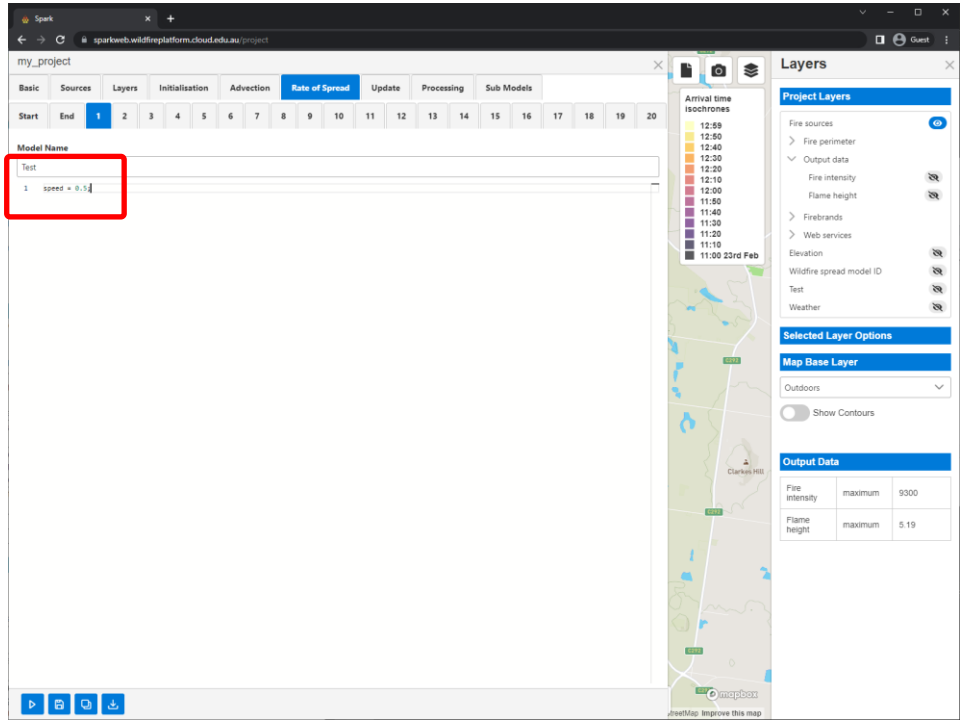
- Layer creation
  - *Any number can be created*
  - *Name available in model scripts for reading/writing*
  - *Must have description to be visualised*
  - *Example ‘test’ layer created called ‘Test’*
- Scripting
  - *Layer is written in update model*
  - *Anywhere where flame height > 1 test is 1*
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

Advanced usage

- Rate-of-spread scripts
  - *Script for each fuel classification type*
  - *Each type is an integer identifier ‘class’*
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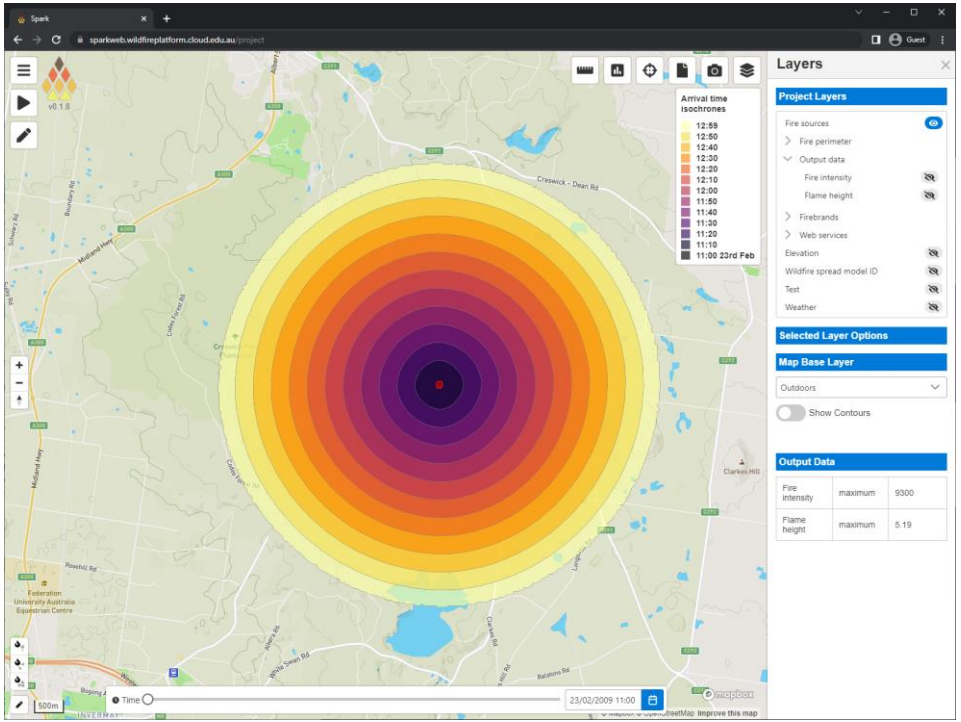
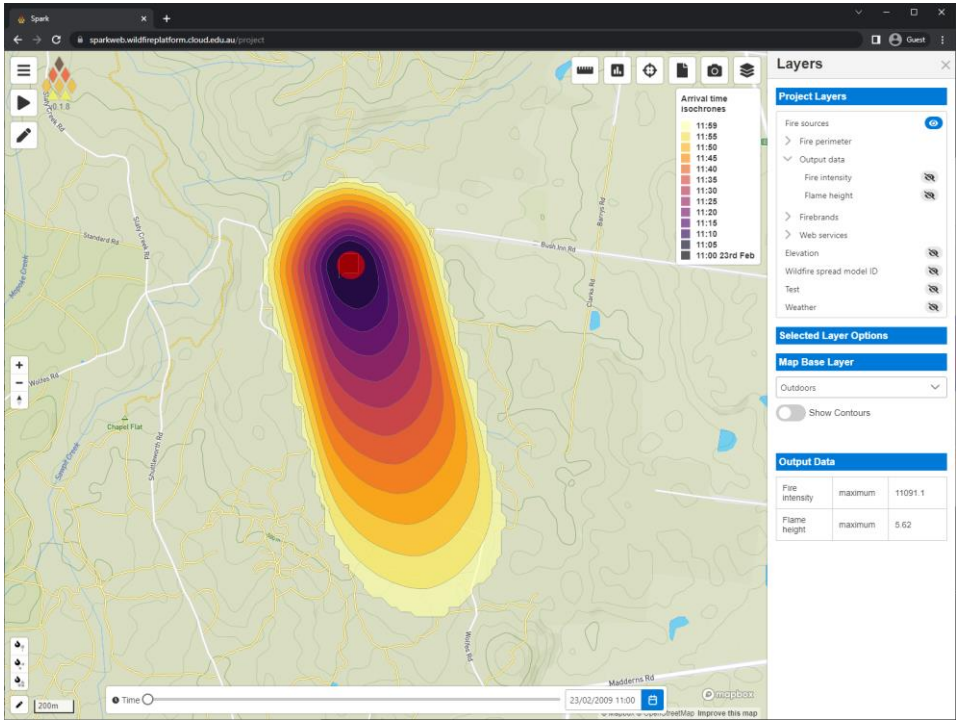
  - *Classes can be named*
- Example 1
  - *Script “speed = 0.5;”*
  - *Sets outward speed to 0.5 m/s*
  - *Resulting fire is circular*



SparkWeb

Advanced usage

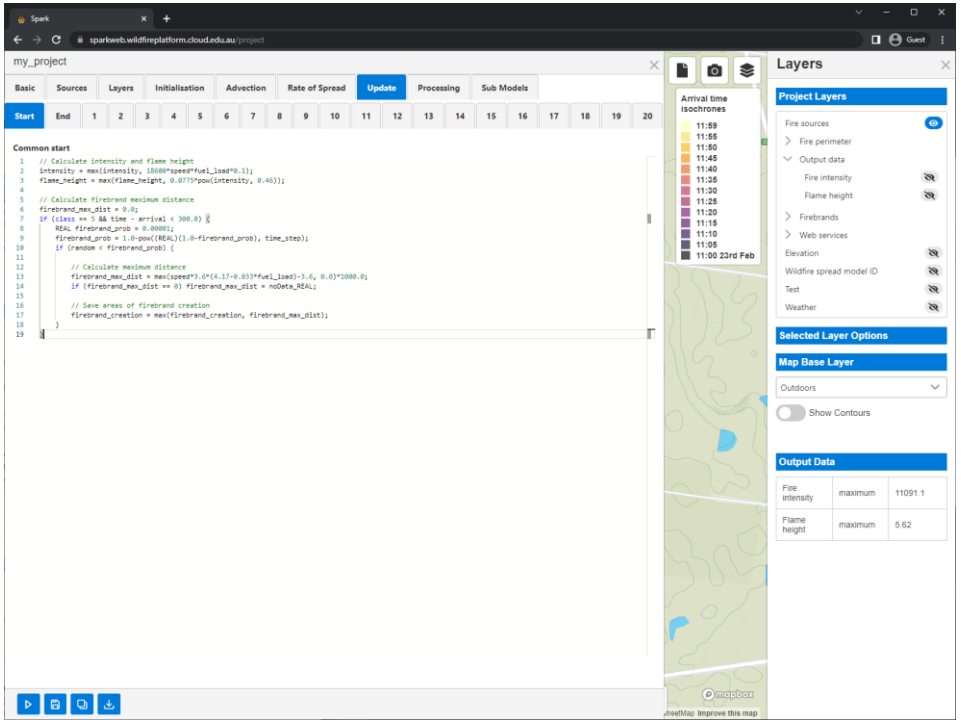
- Rate-of-spread scripts
  - *Script for each fuel classification type*
  - *Each type is an integer identifier ‘class’*
  - *Zero is reserved for un-burnable*
  - *Classes can be named*
- Example 1
  - *Script “speed = 0.5;”*
  - *Sets outward speed to 0.5 m/s*
  - *Resulting fire is circular*
- Example 2
  - *Script “speed = 0.1+0.02*wind;”*
  - *Adds component in wind direction*
  - *Resulting fire grows outwards and moves with wind*



SparkWeb

Advanced usage

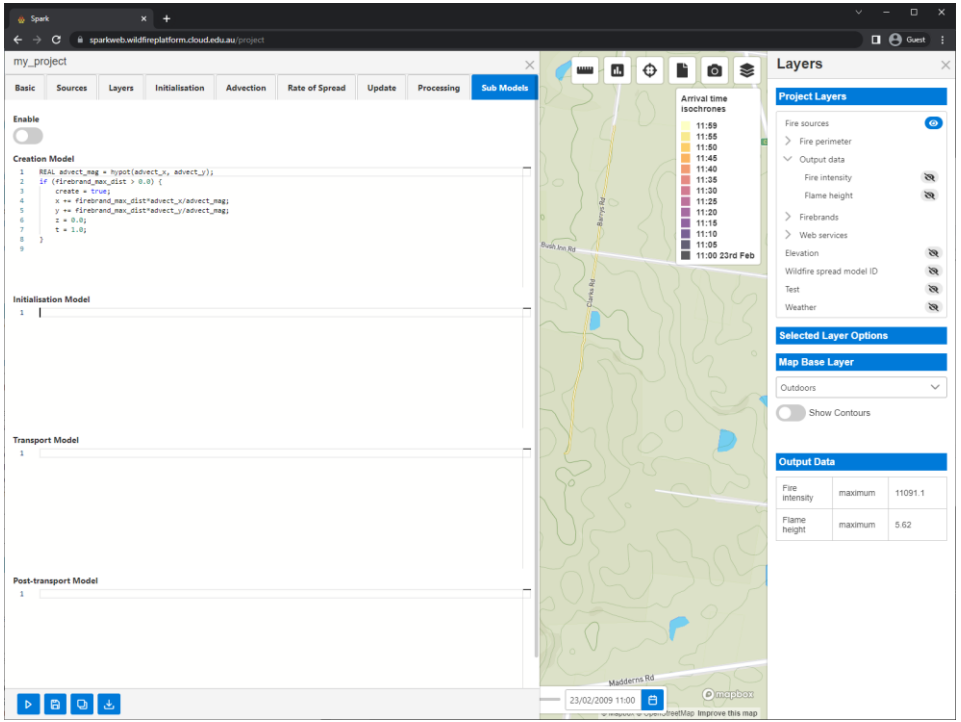
- Firebrand model
  - *McArthur firebrand model*
  - *Requires script to determine creation*



SparkWeb

Advanced usage

- Firebrand model
  - *McArthur firebrand model*
  - *Requires script to determine creation*
- Sub models
  - *Currently only firebrand transport model*
- Firebrand model
  - *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

Advanced usage

- Firebrand model
  - *McArthur firebrand model*
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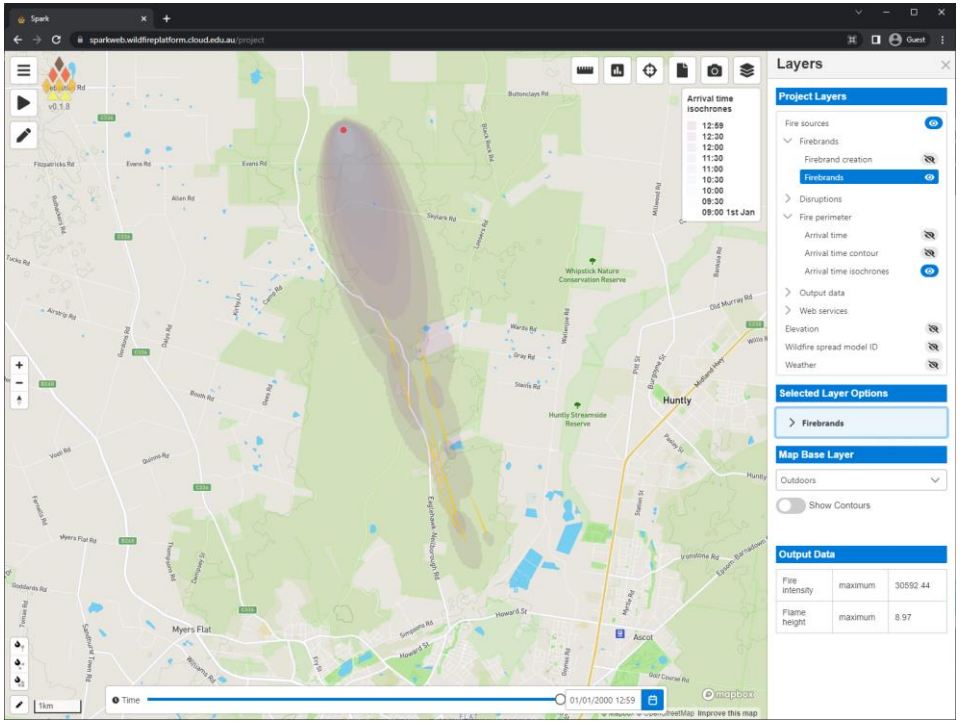
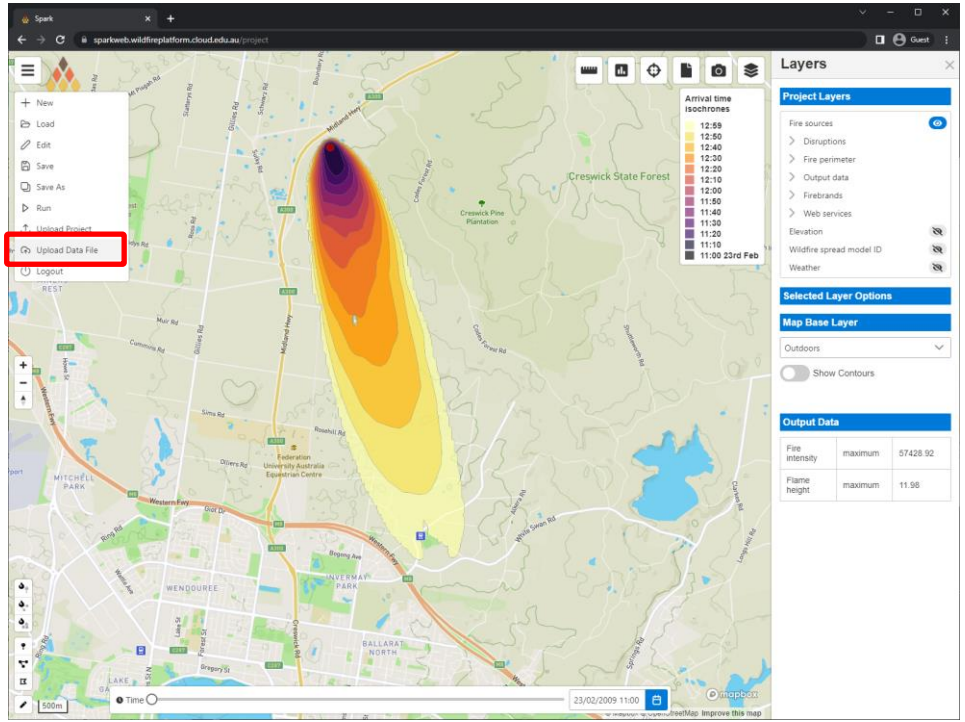
  - *Update model, controls firebrand changes*
  - *Transport model, controls interaction with air flow*
  - *Basic spot fire creation only required one model*
- Visualisation
  - *Firebrands which cause spot fires are visualised with yellow lines from generation to landing points*



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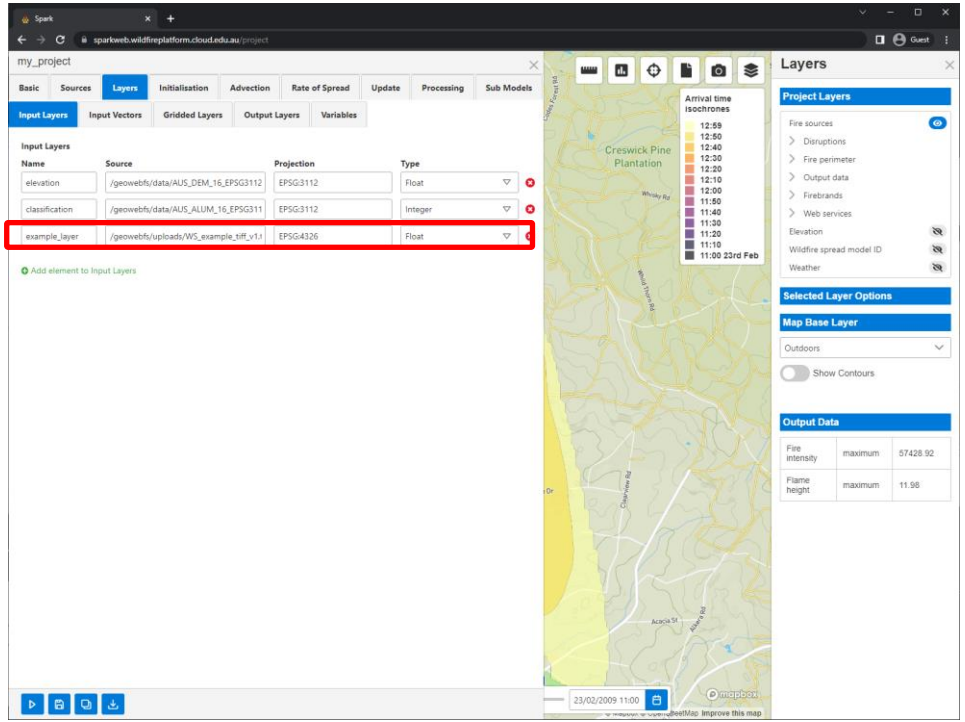
  - *File is uploaded with the path: /geowebfs/uploads/FILENAME*
  - *Input the correct projection and data type as well as a name which can be referred to in the model scripts.*



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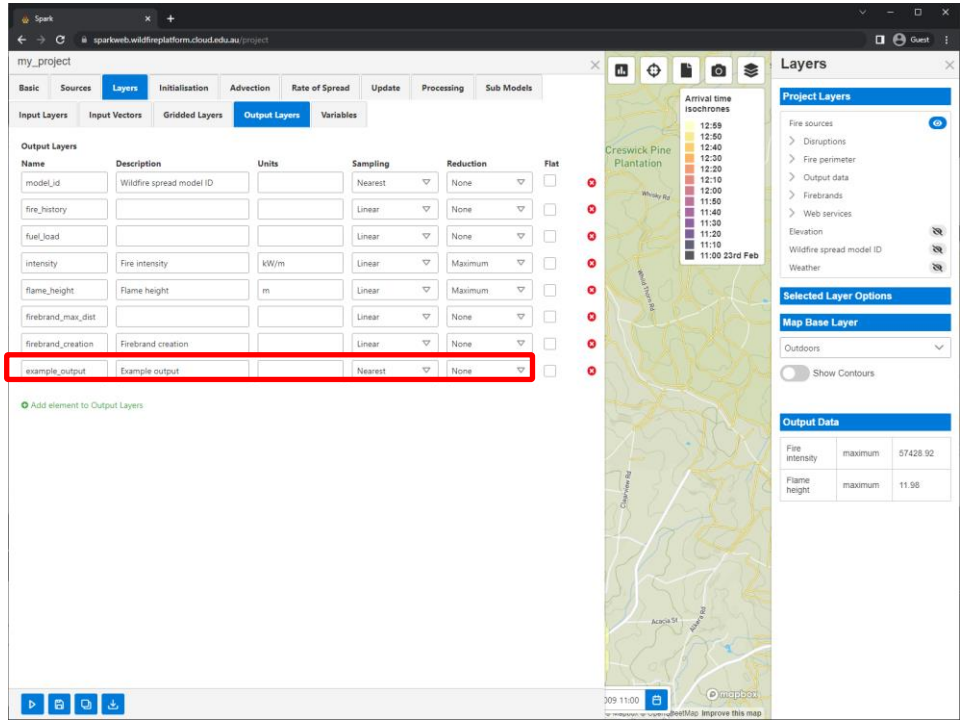
  - *File is uploaded with the path: /geowebfs/uploads/FILENAME*
  - *Input the correct projection and data type as well as a name which can be referred to in the model scripts.*
- Visualising user data layers
  - *Create an output layer*



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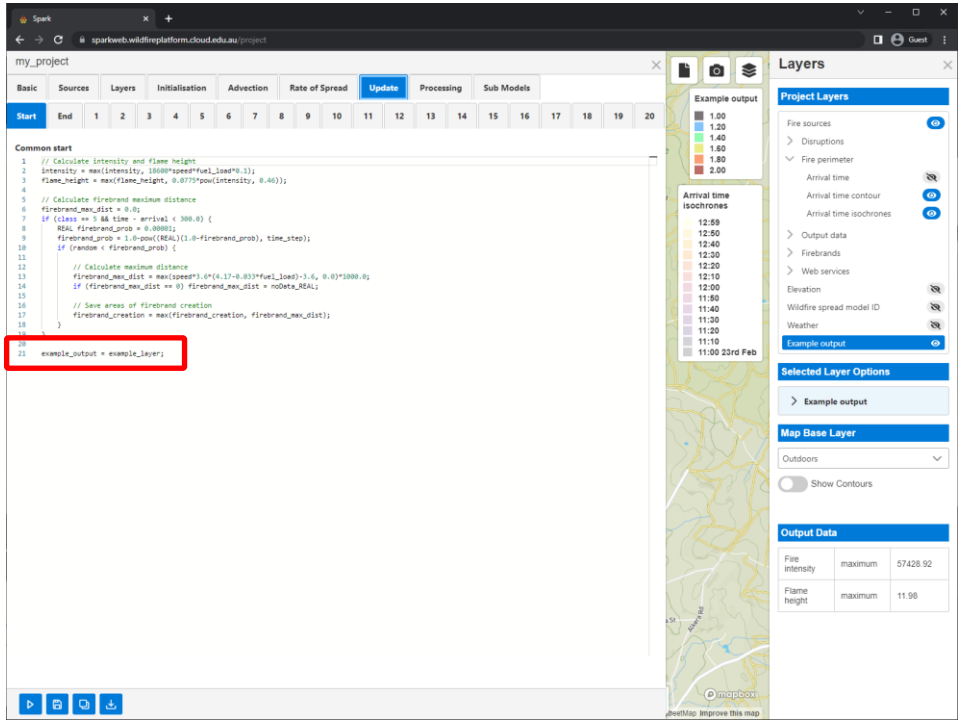
- Visualising user data layers
  - *Create an output layer*
  - *Write to the output in a model script*



SparkWeb

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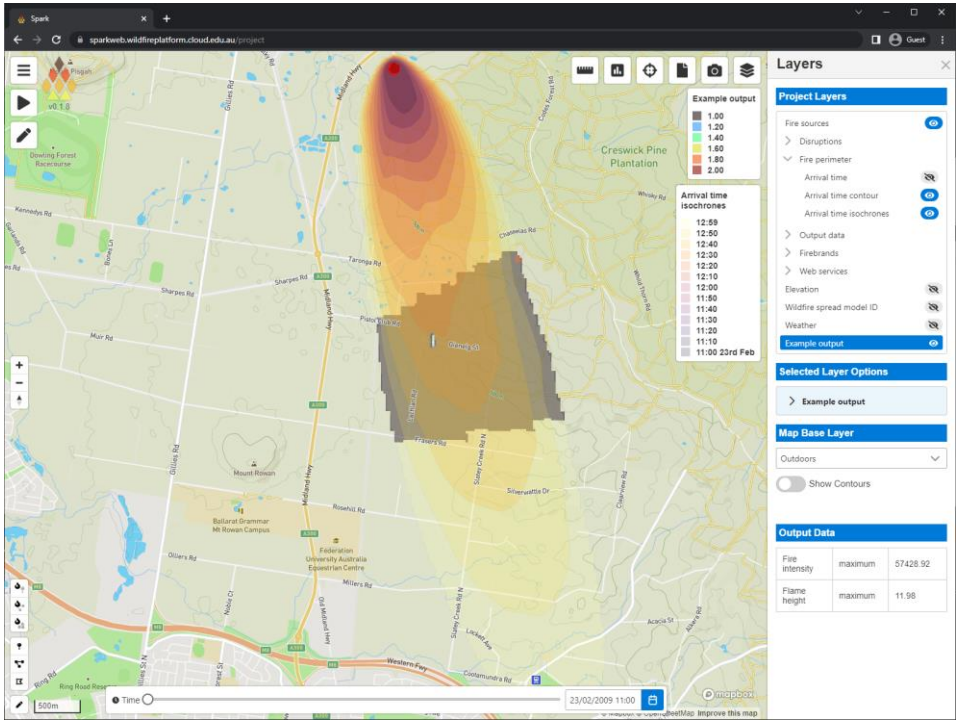
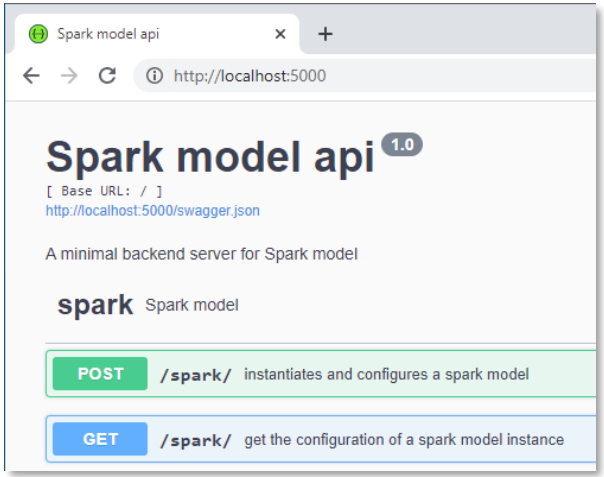
- Visualising user data layers
  - *Create an output layer*
  - *Write to the output in a model script*
  - *Run simulation again to view output*
  - *Your layer name can be used in Initialisation, Rate of Spread and Update models*



SparkWeb

Spark server

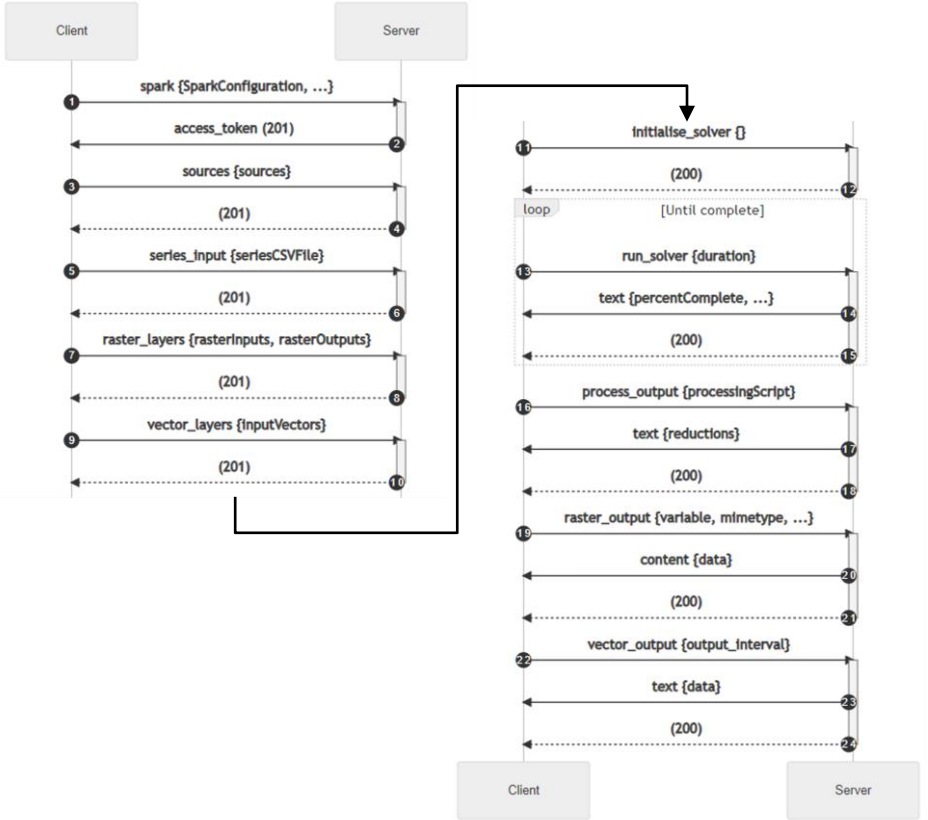
- Web API
  - *Services calls from SparkWeb*
  - *Can be called directly to run simulations/serve outputs*
  - *All models sent to server*



SparkWeb

Spark server

- Web API
  - *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

Spark server

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  - */spark/raster_output – Get gridded output (tiff/json)*
  - */spark/vector_output – Get vector output (shp/geojson)*
  - *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"
    }
})
```