Fire pixels, a multi-layered approach to derive smoke emission fluxes and enhance skills in smoke forecasting

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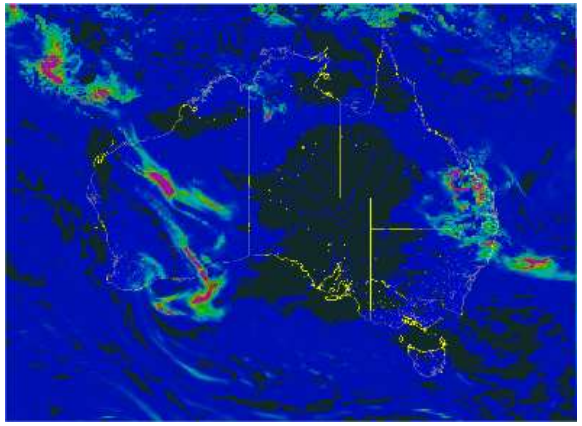
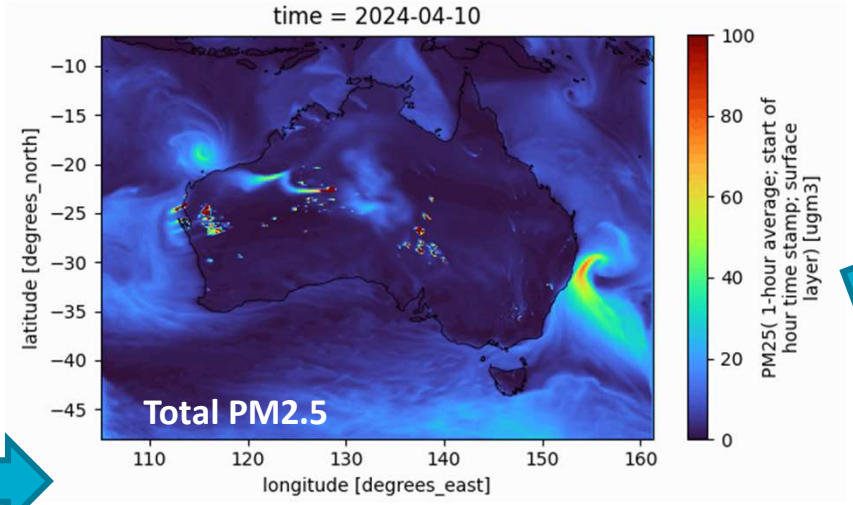
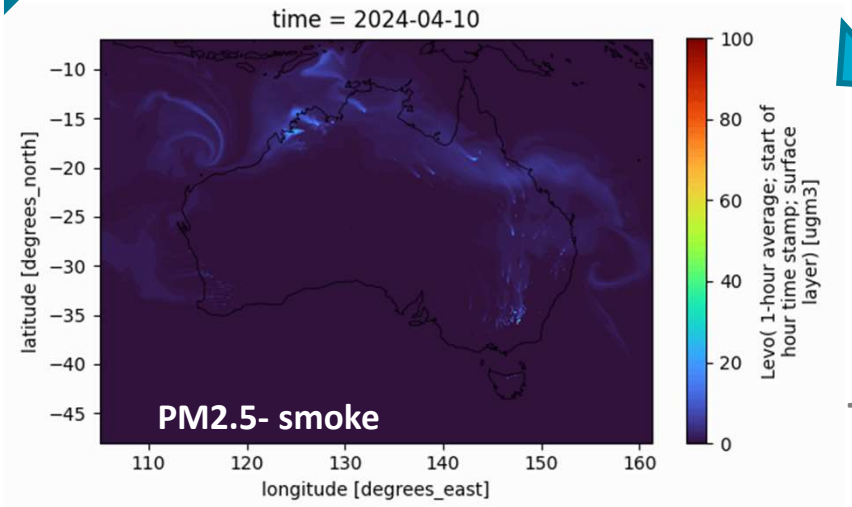
How are the national forecasts generated?

Weather forecasts (Bureau of Meteorology)

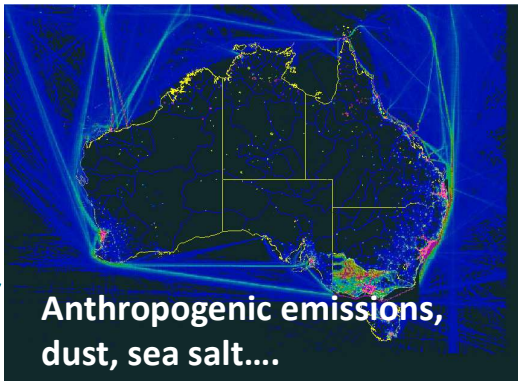


72-hour forecasts;
9 km spatial (national);
1.6 to 3 km spatial (regional)



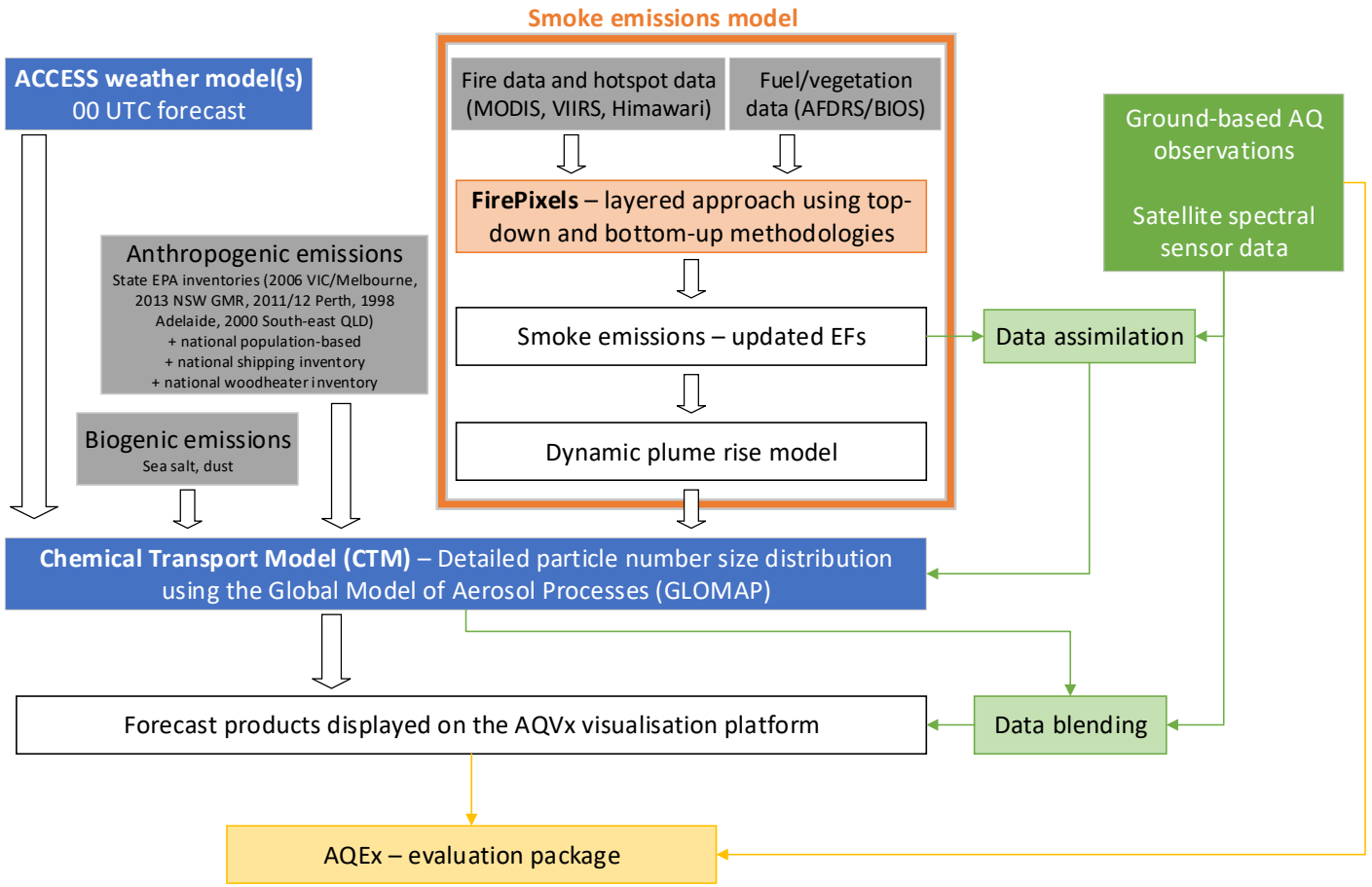


National emissions



-other forecast species include NO_2 and O_3

Workflow diagram of the CSIRO Prototype National Air Quality Forecast System (AQFx_p)



How are smoke emission fluxes derived?

Top – down method:

$$\text{Emissions}_i = \alpha \times \int_{t1}^{t2} \text{FRP(t)dt} \times \boldsymbol{EF_i}$$

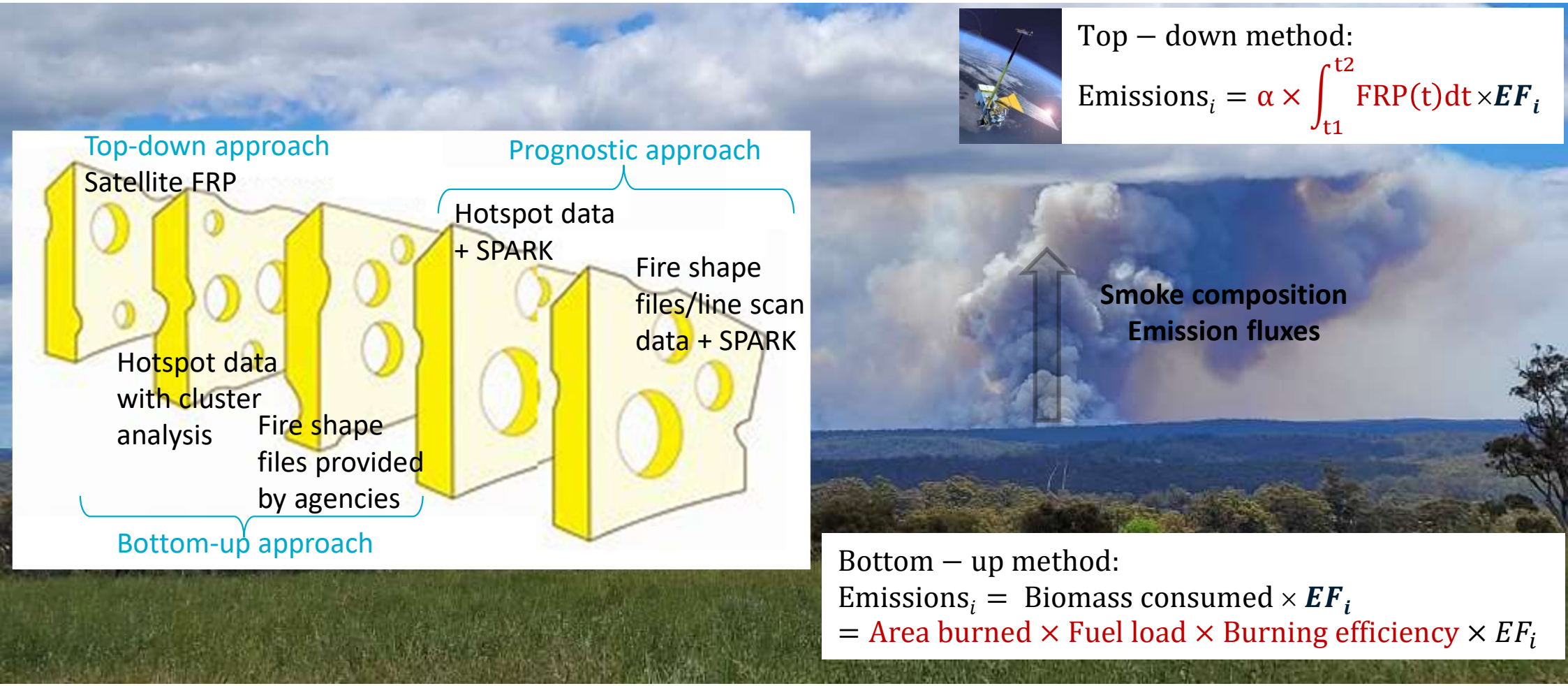
Smoke composition
Emission fluxes

Bottom – up method:

$$\text{Emissions}_i = \text{Biomass consumed} \times \boldsymbol{EF_i}$$

$$= \text{Area burned} \times \text{Fuel load} \times \text{Burning efficiency} \times \boldsymbol{EF_i}$$

Enhance smoke emissions module using a multi-layered approach



Top − down method:

$$\text{Emissions}_i = \alpha \times \int_{t1}^{t2} \text{FRP(t)dt} \times \boldsymbol{EF_i}$$

Bottom − up method:

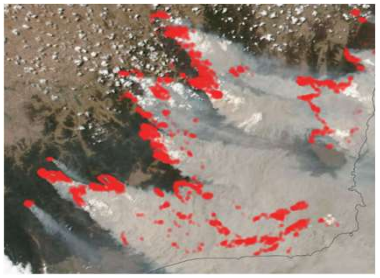
$$\text{Emissions}_i = \text{Biomass consumed} \times \boldsymbol{EF_i}$$

$$= \text{Area burned} \times \text{Fuel load} \times \text{Burning efficiency} \times EF_i$$

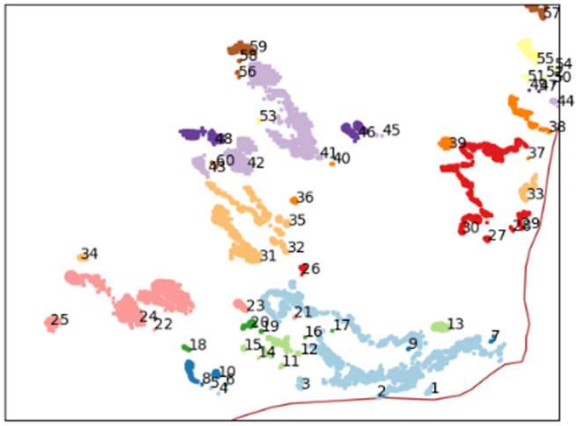
Fire pixels – a multi-layered approach

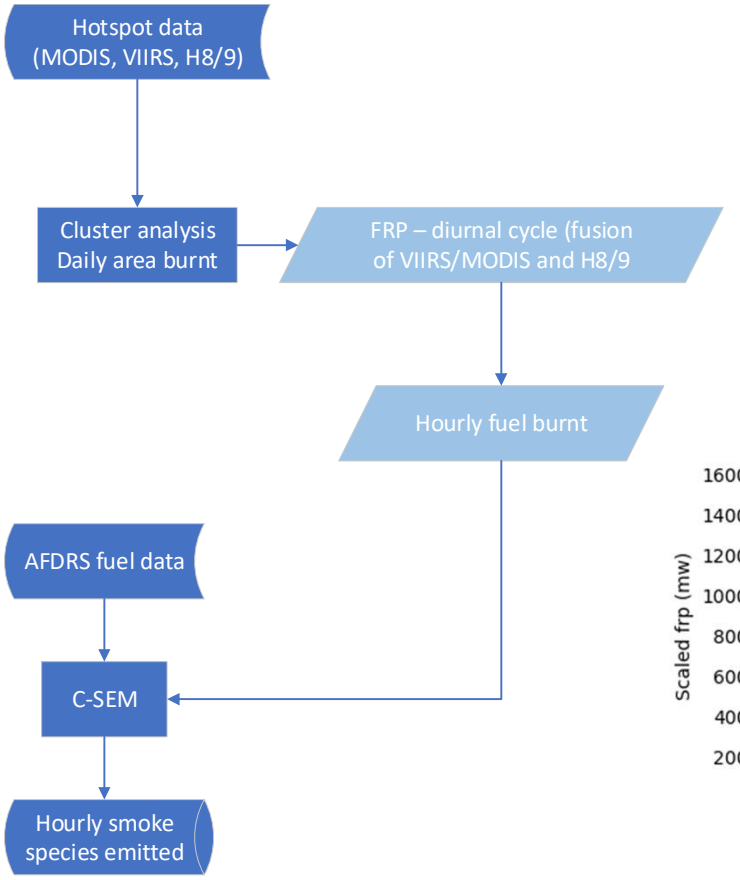
Top-down method

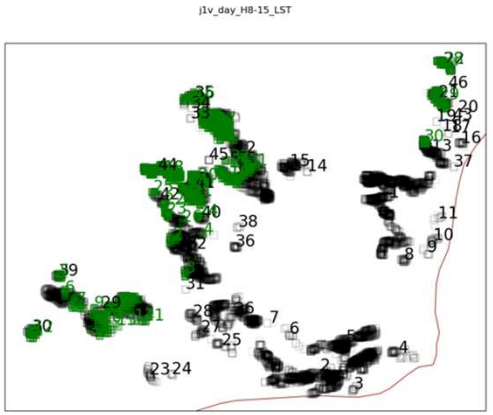
1. Suomi NPP/VIIRS hotspot location.



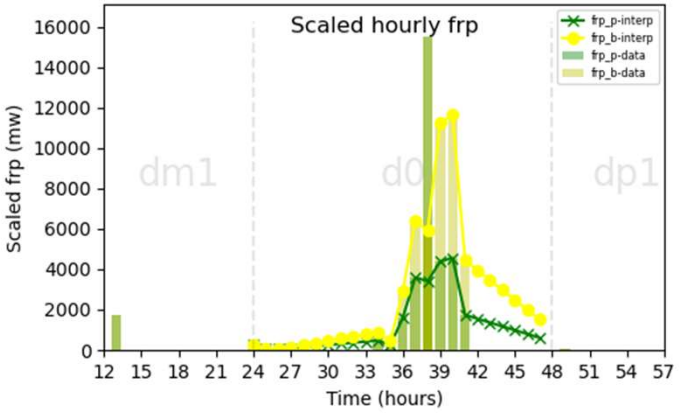
2. Cluster analysis (60 fire clusters)







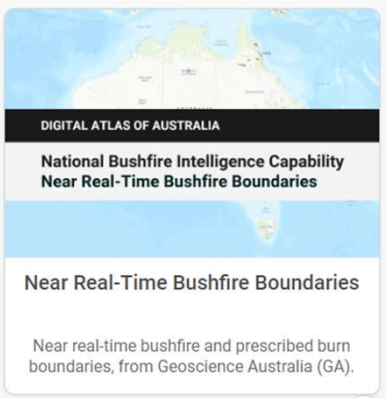
3. H8/9 clusters (green) which overlap VIIRS (black) clusters



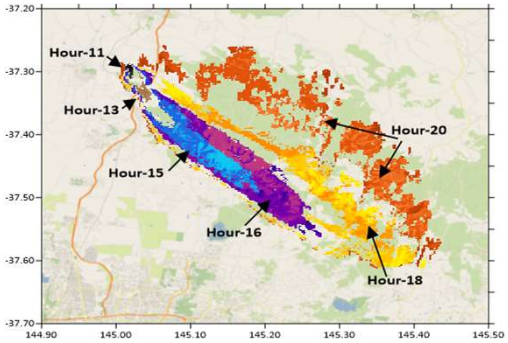
4. Estimated hourly FRP using 10-min H8 data

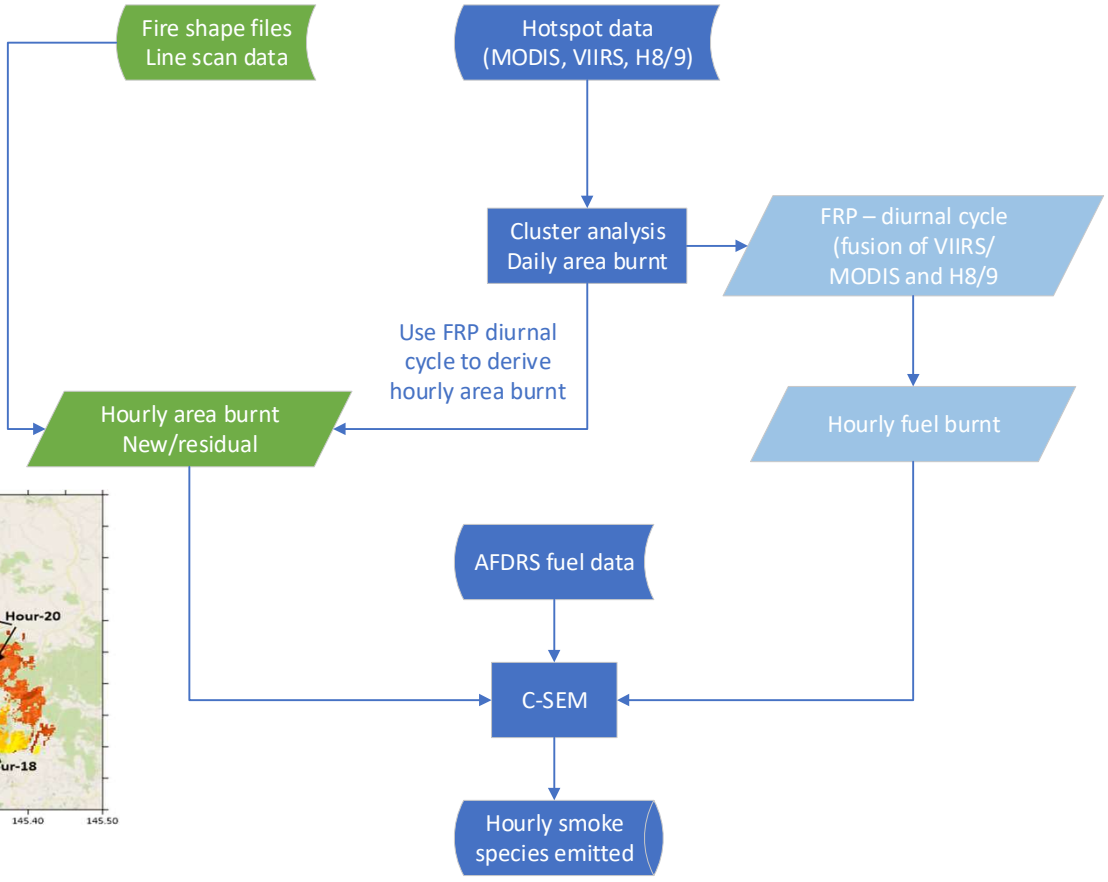
Fire pixels – a multi-layered approach

Bottom-up method



https://digital.atlas.gov.au/pages/8b124790a8f54ccd9b3288288e21cfd2#c7y5p5u7s





Daily area burnt:

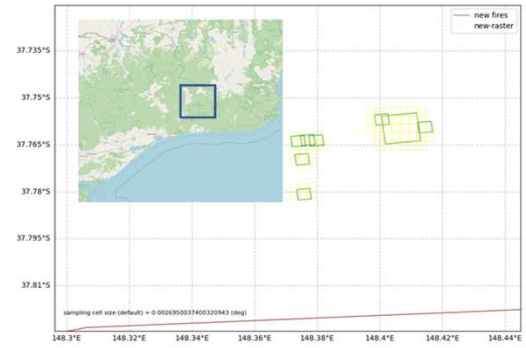
- Provided by fire shape files
- Calculated from satellite hotspot density, and empirical relationships between land category and area burnt.

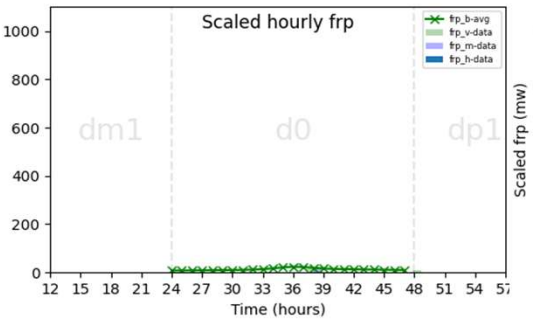
Daily fuel burnt:

- Calculated from fine and coarse woody fuel load and burning efficiency.

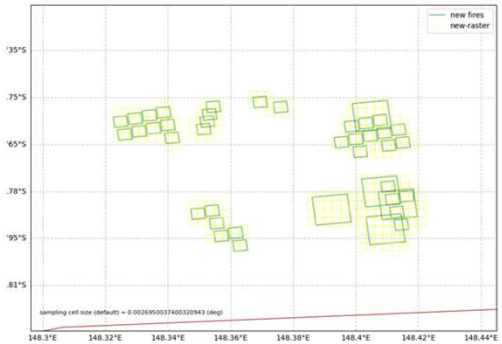
Distinguishing between new and residual fires

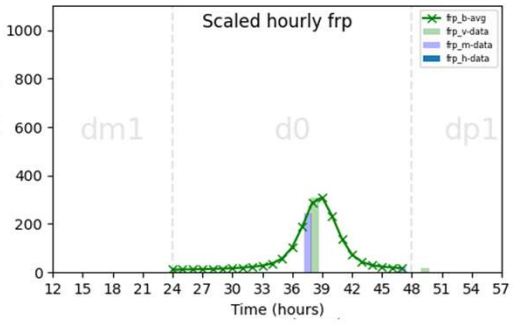
4th April 2017



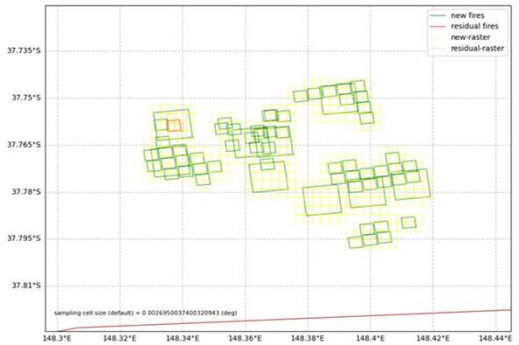


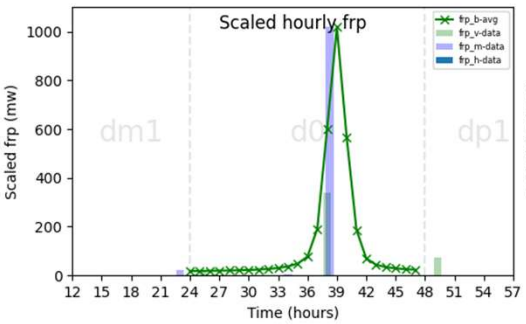
5th April 2017



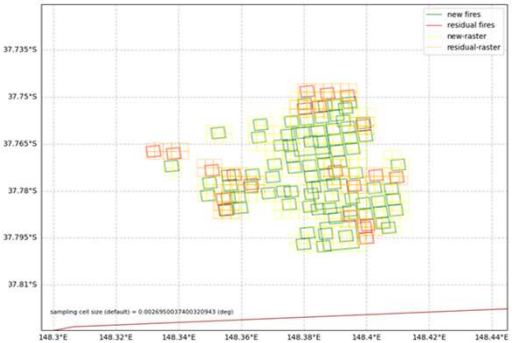


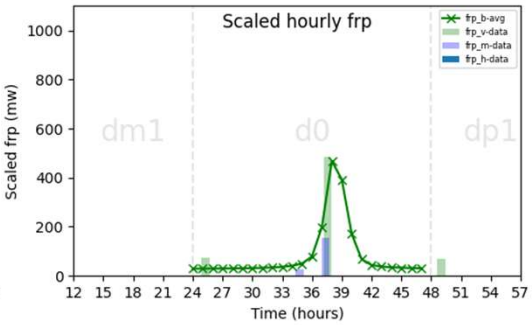
6th April 2017





7th April 2017

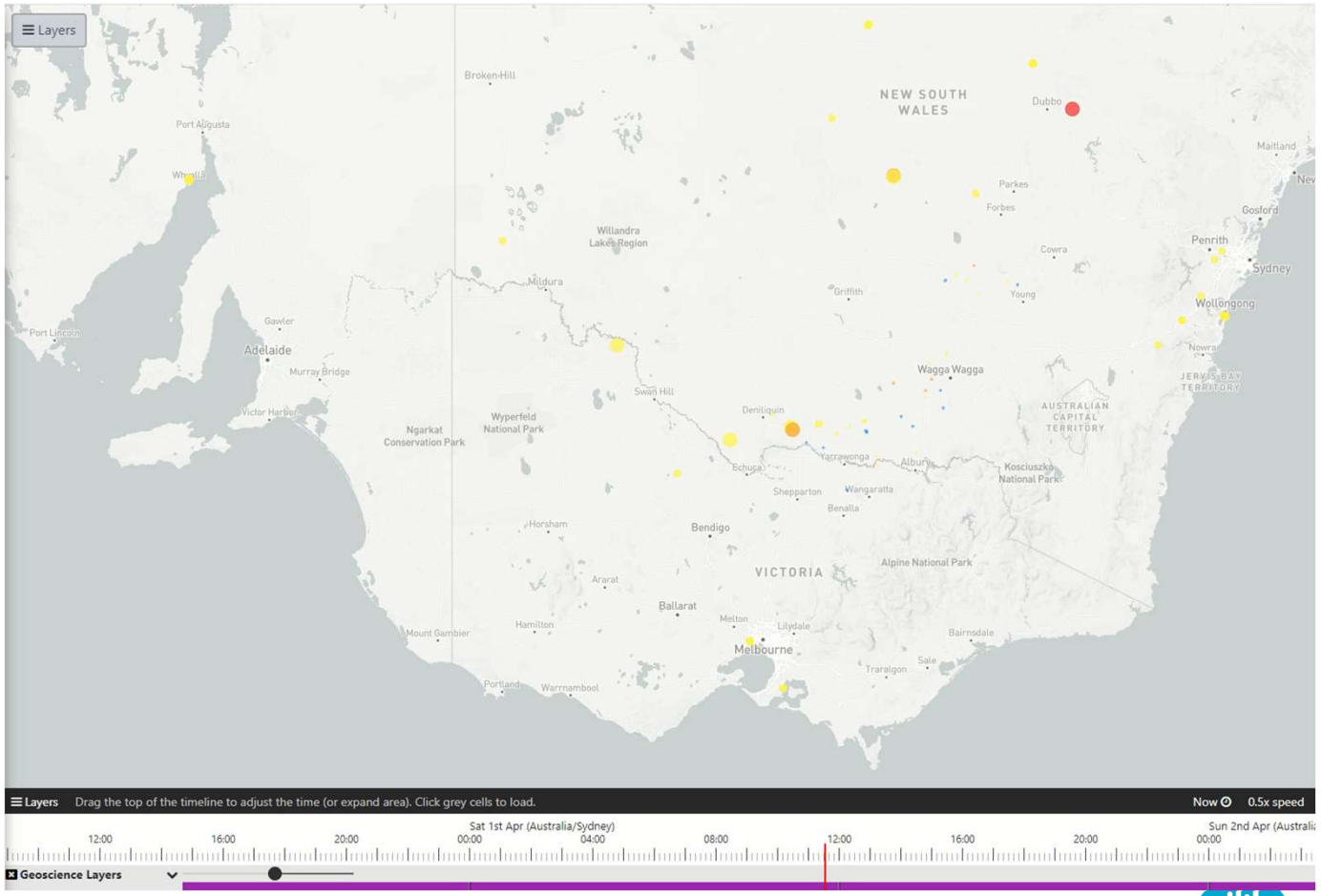




Hotspot detection- agricultural burning

Significant hotspot activity over central VIC/NSW captured by the MODIS/VIIRS satellite overpass at ~1pm each day. This is primarily due to agricultural burning.

The hotspot activity is significantly lower overnight (as captured by the 1am VIIRS satellite overpass).
This may be due to short-lived fast-moving burns (e.g., agricultural burns) or under-canopy smouldering fires not well captured by MODIS/VIIRS.

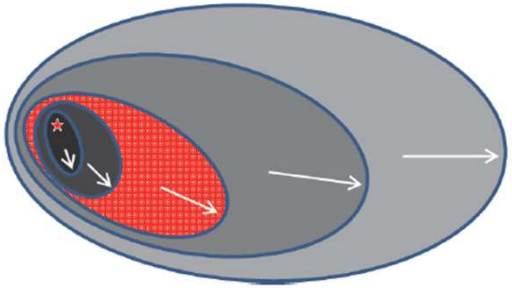


Active fire hotspot locations using MODIS and VIIRS satellite observations between 1-5 April 2023

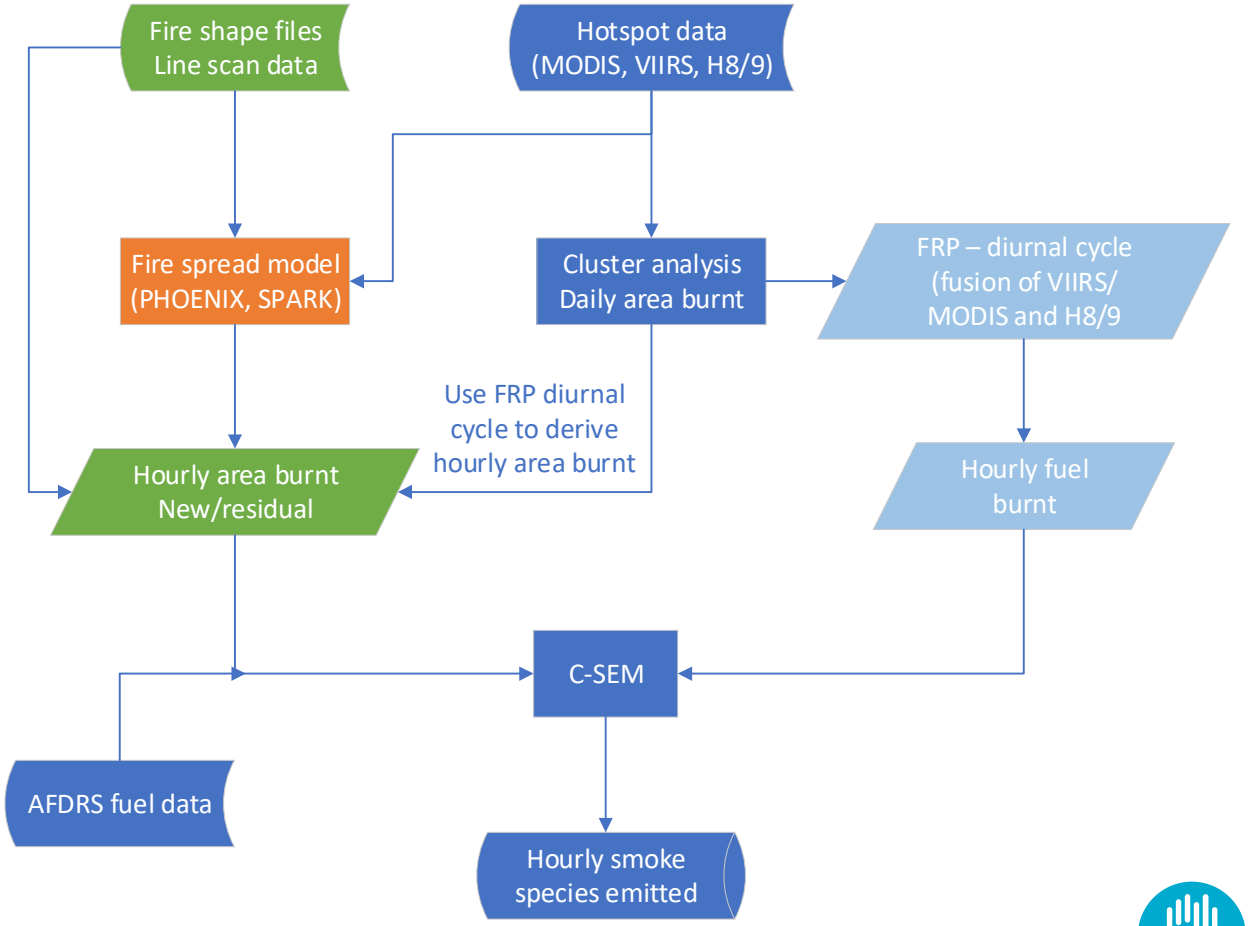
Fire pixels – a multi-layered approach

Prognostic method

- Area burnt is derived from Phoenix Rapid Fire/SPARK fire spread modelling



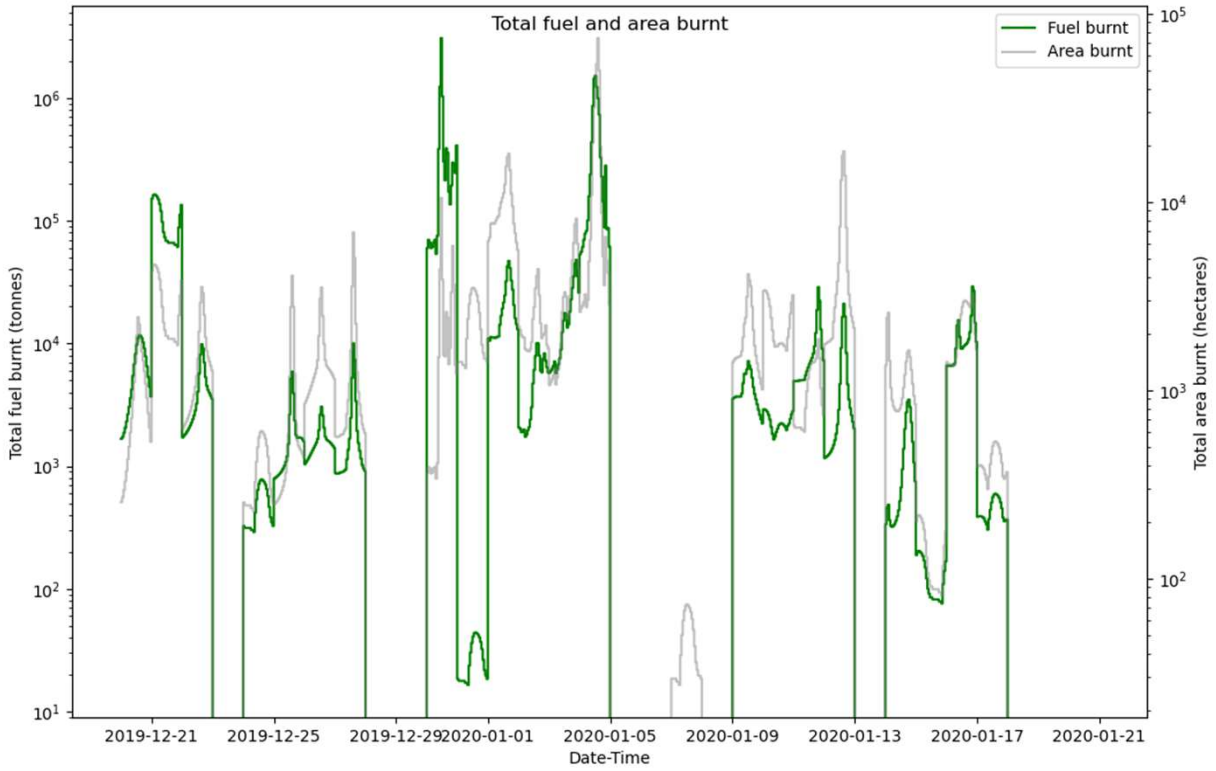
PHOENIX FireFlux bushfire simulator with modifications - at the end of a time step the area burnt is identified as a polygon and the total amount of fuel consumed is calculated



Total fuel and area burnt using satellite data

The data gaps correspond to days with significant cloud cover or smoke cover when thermal anomalies are not detected.

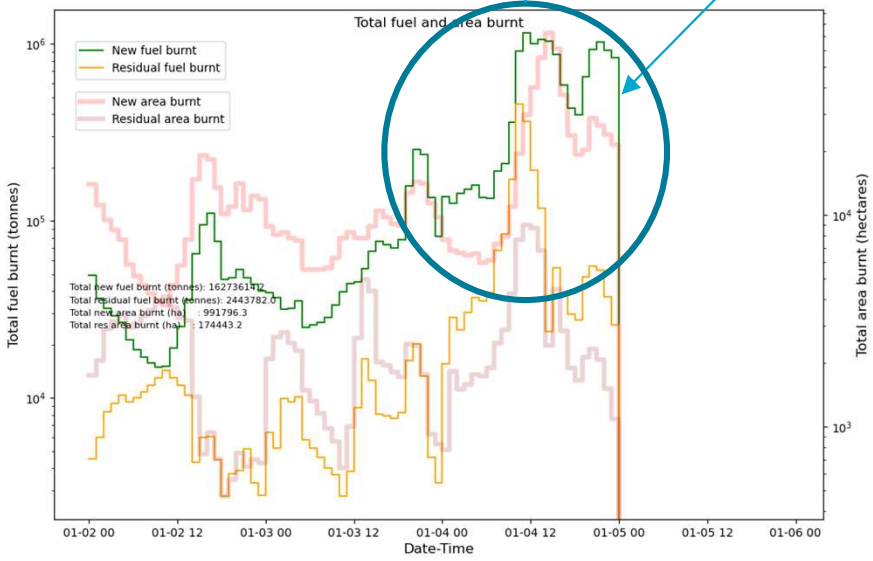
Data gaps are filled using a persistence assumption or prognostic modelling (Phoenix or SPARK).



The use of historical vs forecast mode for estimating smoke emissions

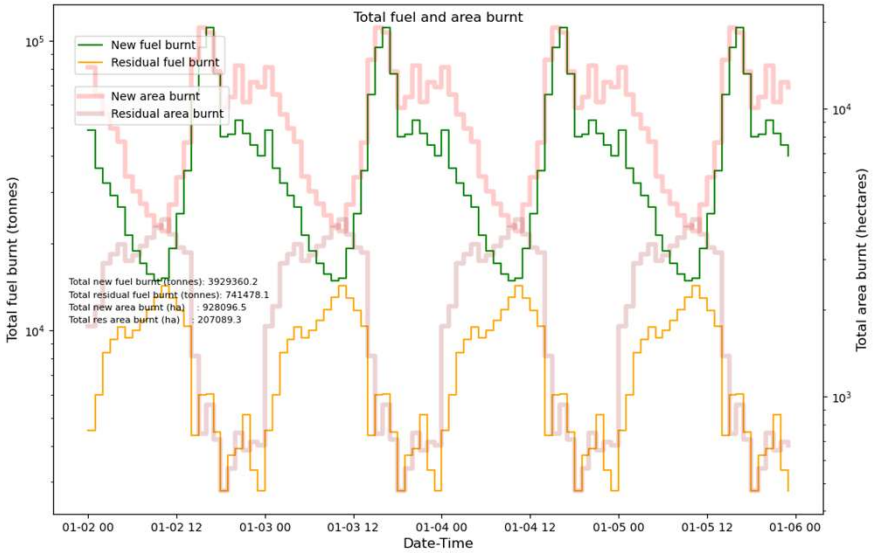
Increased fire spread on 4 Jan

Cloud cover?



Historical mode – an increase in fire activity and smoke emissions on 4 January 2020, followed by no emissions due to missed fire detections because of dense cloud cover.

Use persistence

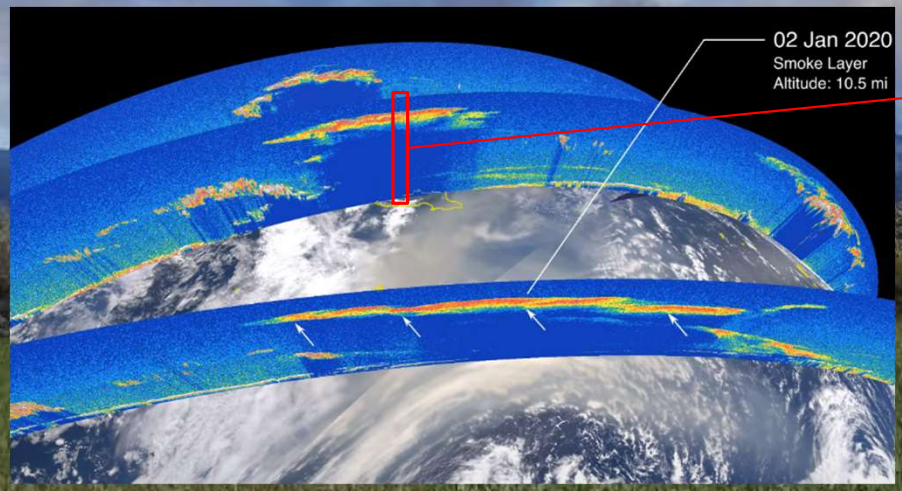


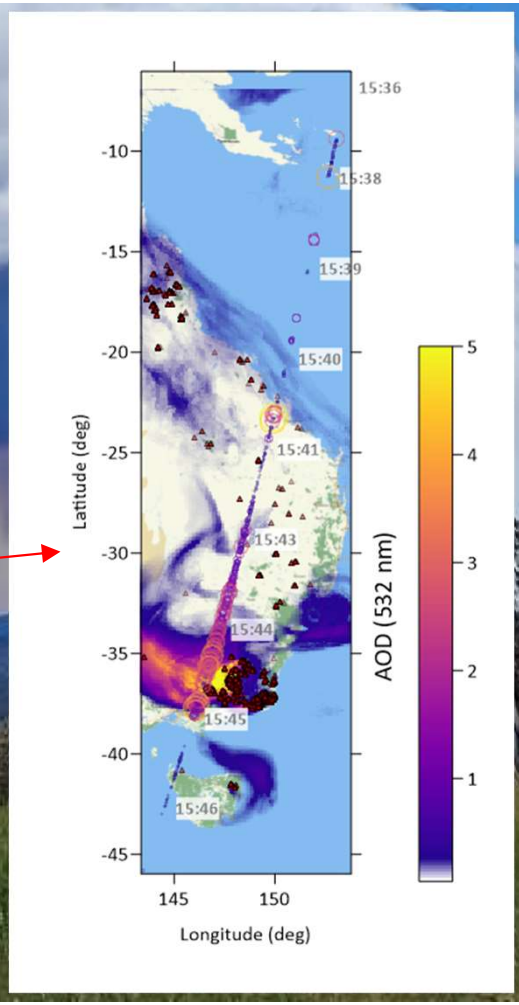
Forecast mode – assume persistence of fire activity for the forecast days until new satellite data becomes available. The increased fire activity and smoke emissions on 4 January 2020 was not captured, but smoke emissions did not cease due to cloud cover.

Derive emissions from satellite AOD or CO observations

Top – down approach:

1. Derive emissions using FRP, which is related to the rate of biomass combustion
2. Derive particle emissions using satellite AOD observations (MODIS, Himawari)
3. Derive emission rates of trace gases (e.g. CO, NO_2) using the TROPOspheric Monitoring Instrument (TROPOMI) observations.





Thank you

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