AQFx- a national smoke forecasting system: From emissions to forewarning

Fabienne Reisen (on behalf of the AQFx project team)
13 May 2024

Australia's National Science Agency

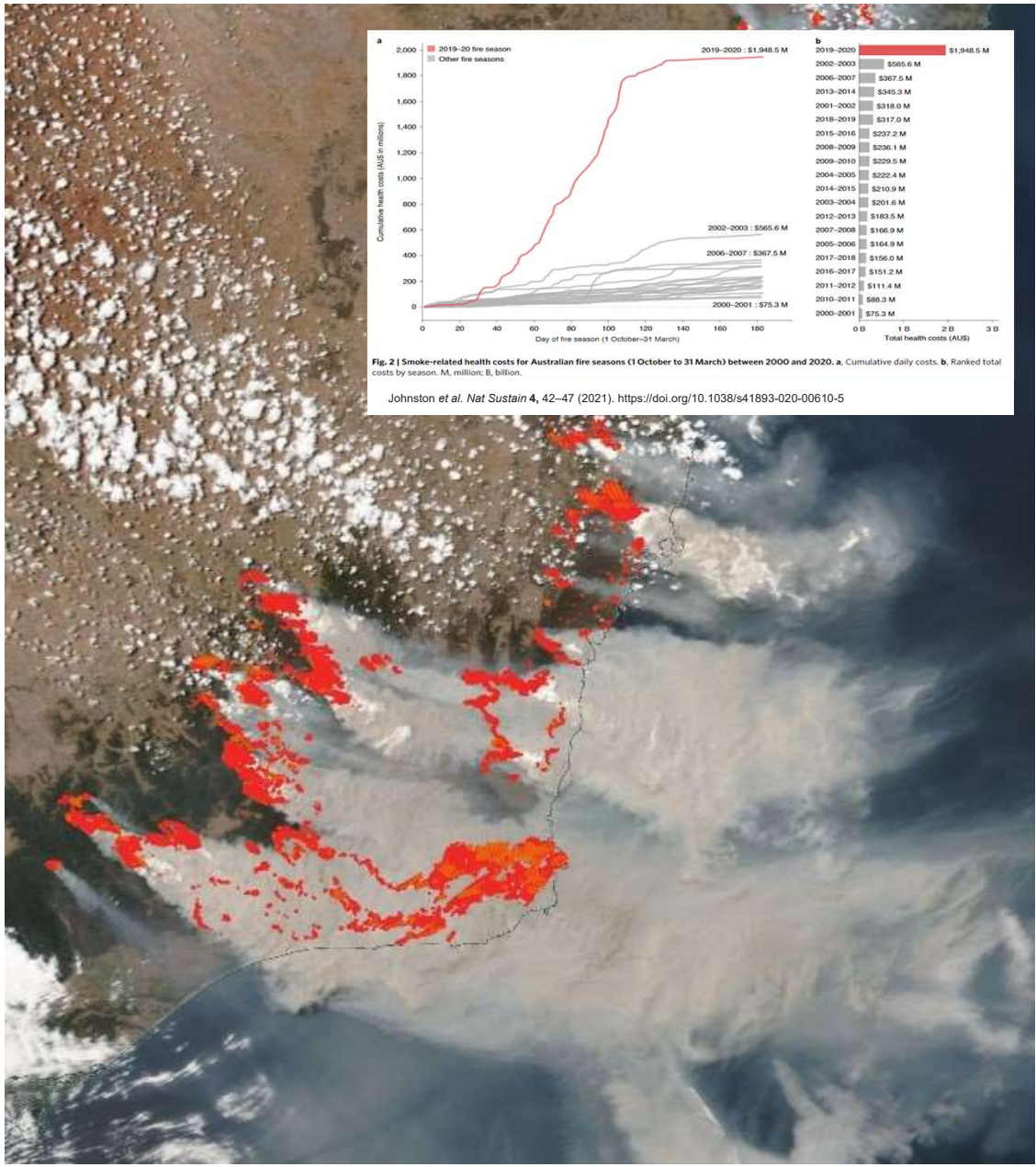
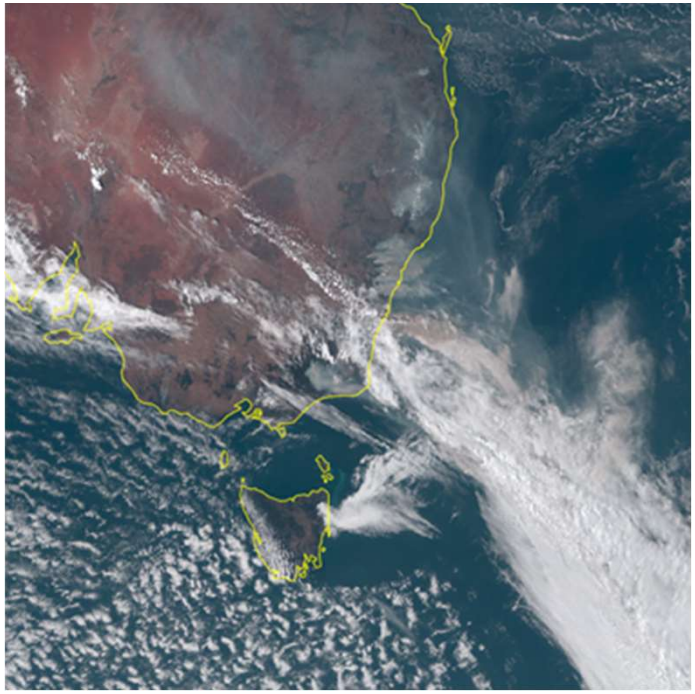


Fig. 2 | Smoke-related health costs for Australian fire seasons (1 October to 31 March) between 2000 and 2020. a, Cumulative daily costs. **b**, Ranked total costs by season. M, million; B, billion.

Johnston *et al*. *Nat Sustain* **4,** 42–47 (2021). https://doi.org/10.1038/s41893-020-00610-5

National Smoke Forecasting Capability

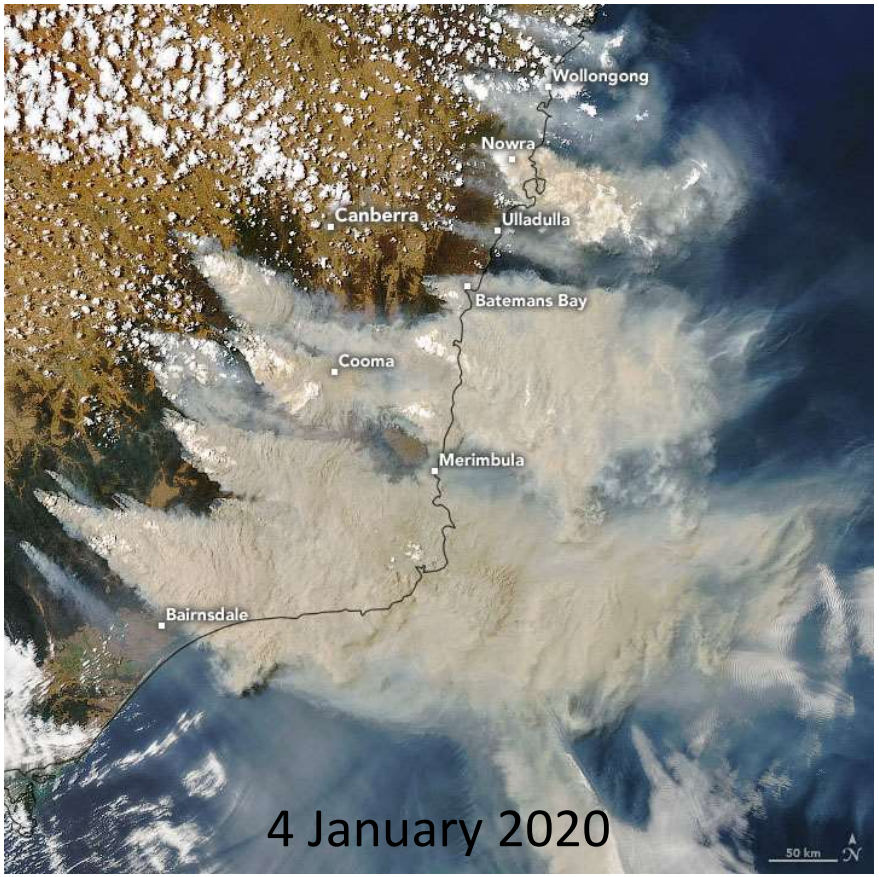
The extent of the 2019/20 bushfires highlighted the urgent need for a national smoke forecasting capability to protect health across Australia.



Alignment to Royal Commission recommendation 14.2 National Air Quality Forecasting Capability:

Australian, state and territory governments should develop national air quality forecasting capabilities, which include broad coverage of population centres and apply to smoke and other airborne pollutants, such as dust and pollen, to predict plume behaviour.

Air Quality Impacts from Bushfires and Burn-offs



AQFx - CSIRO

- Development and evaluation of the underpinning science in air quality and smoke forecasting

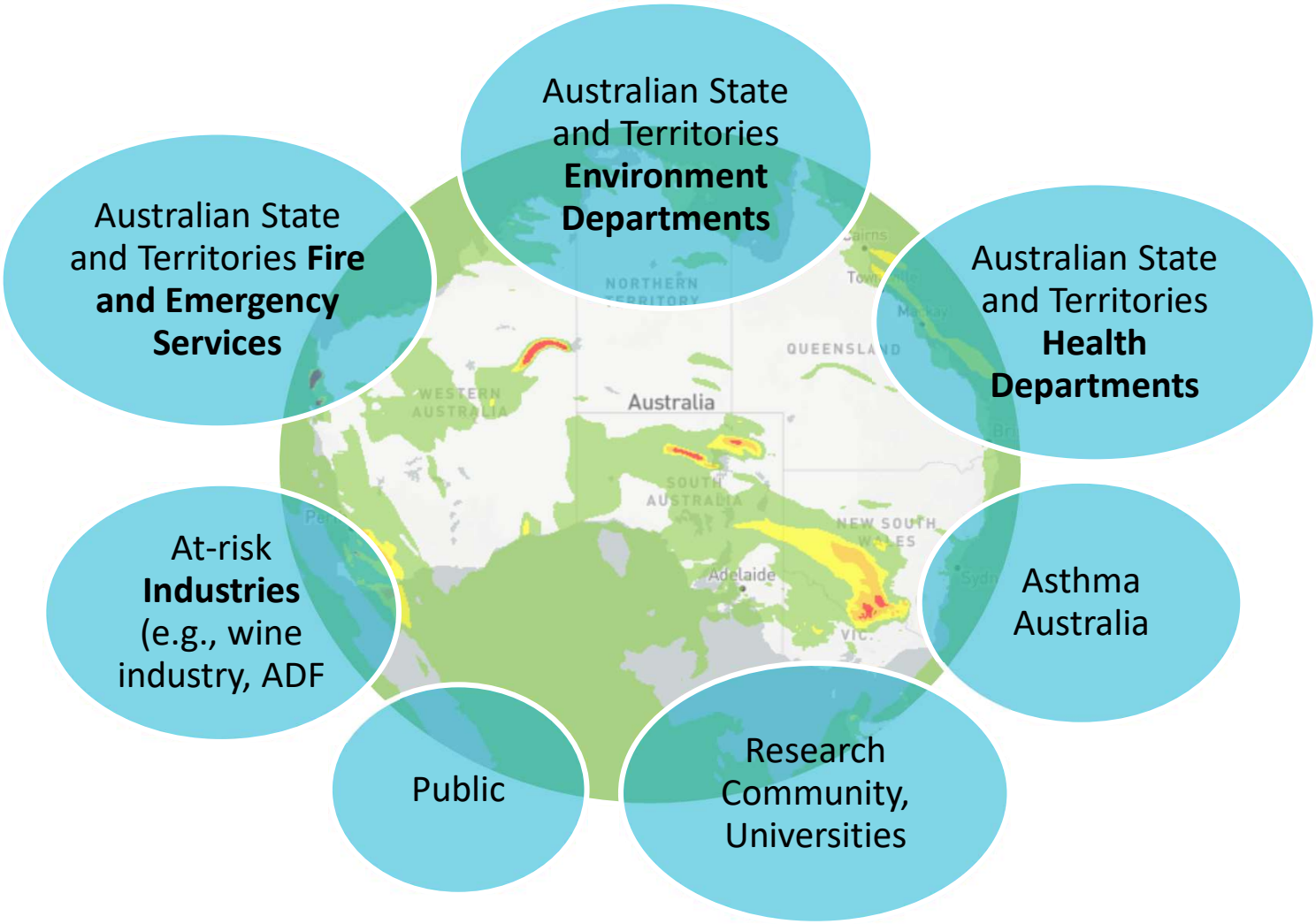
ASDS – Bureau of Meteorology

- Operational system providing national smoke forecasts

AQVx

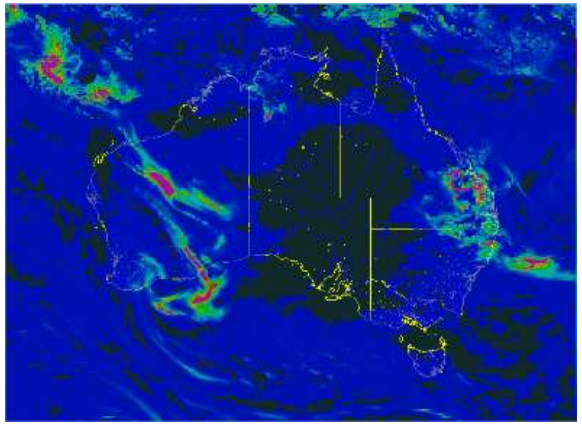
- Powerful and intuitive web-based application to visualise the past, current and forecast of air quality (and smoke) across Australia.

Stakeholder and End-user Community

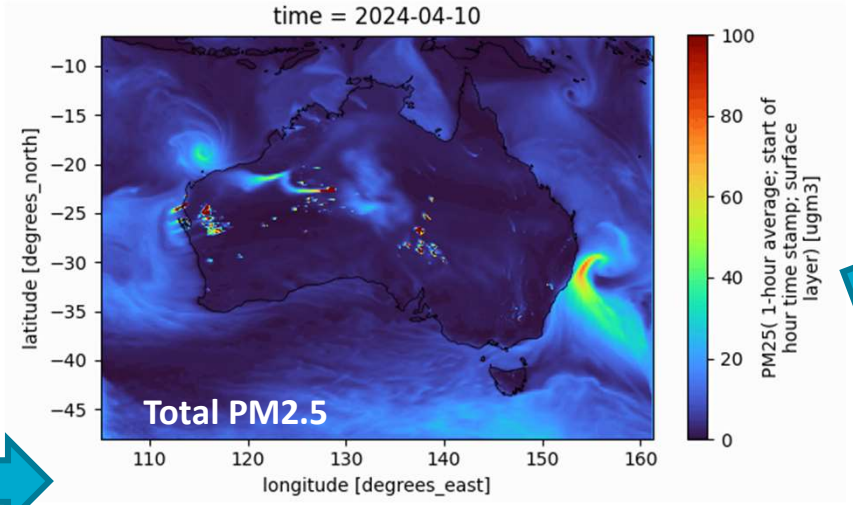


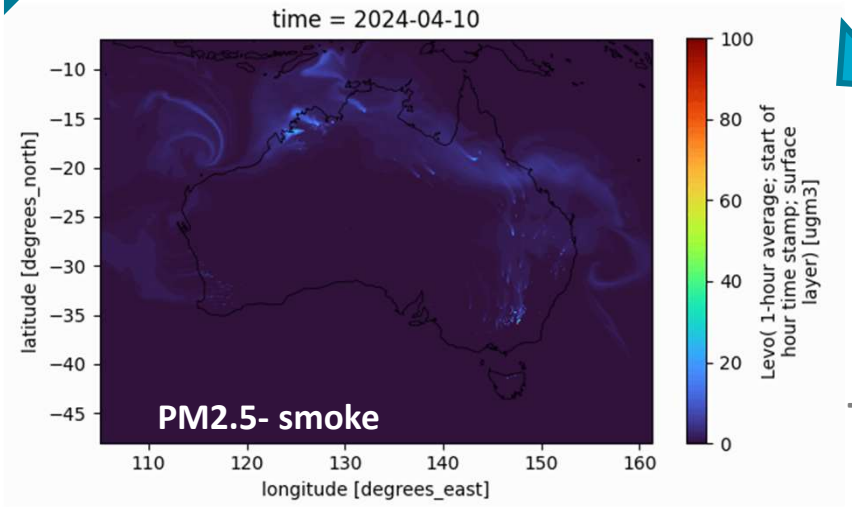
How are the national forecasts generated?

Weather forecasts (Bureau of Meteorology)

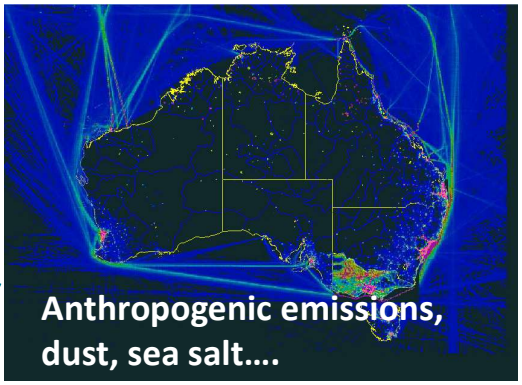


72-hour forecasts;
9 km spatial (national);
1.6 to 3 km spatial (regional)



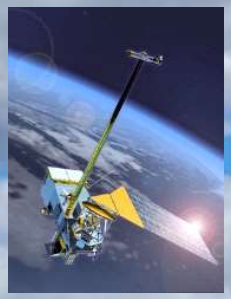


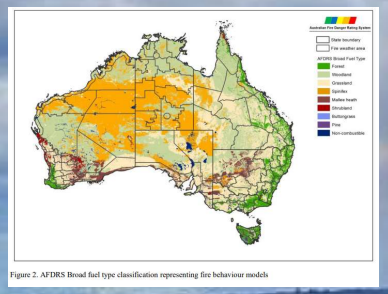
National emissions

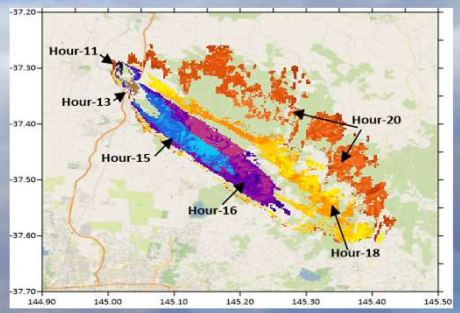


-other forecast species include NO_2 and O_3

How are smoke emissions derived?





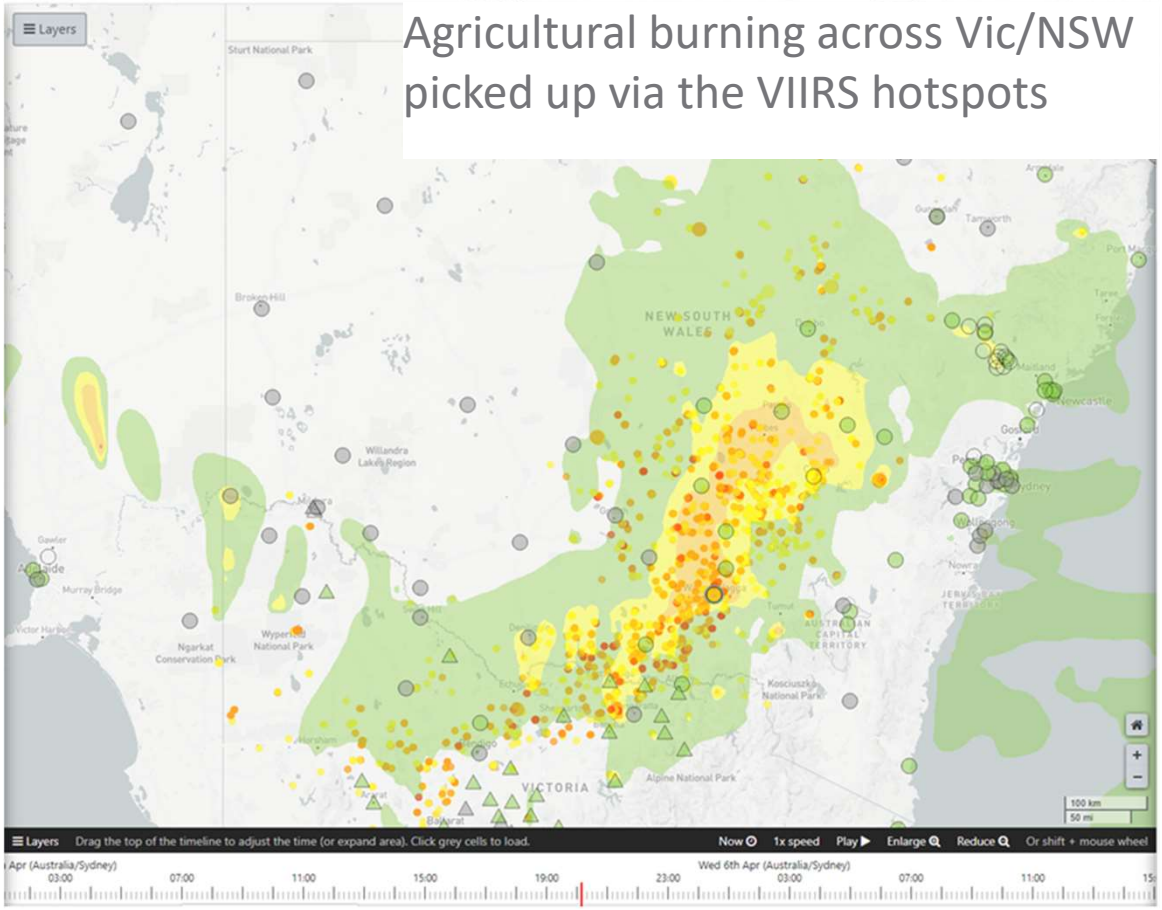


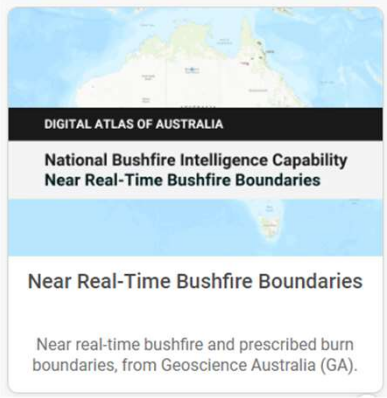
Smoke composition
Emission fluxes

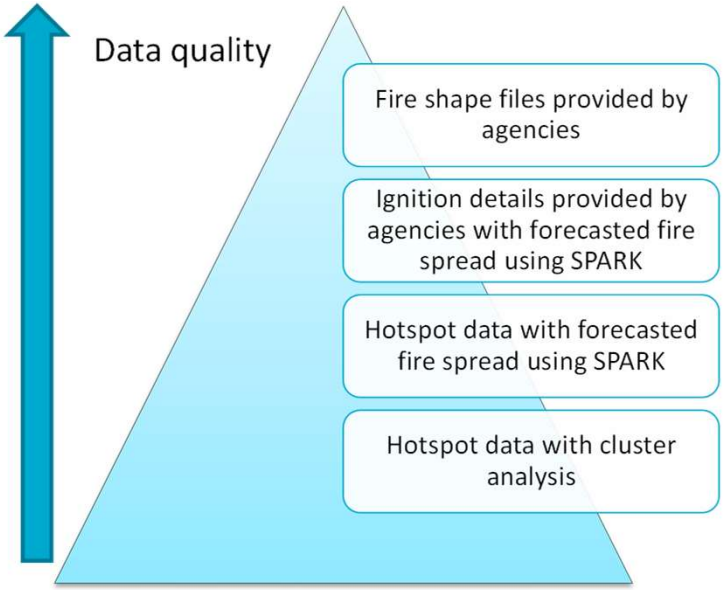
PM2.5 Emissions = Amount of biomass consumed× $\boldsymbol{EF}$ (PM2.5)

Hotspot Detection- Agricultural Burning

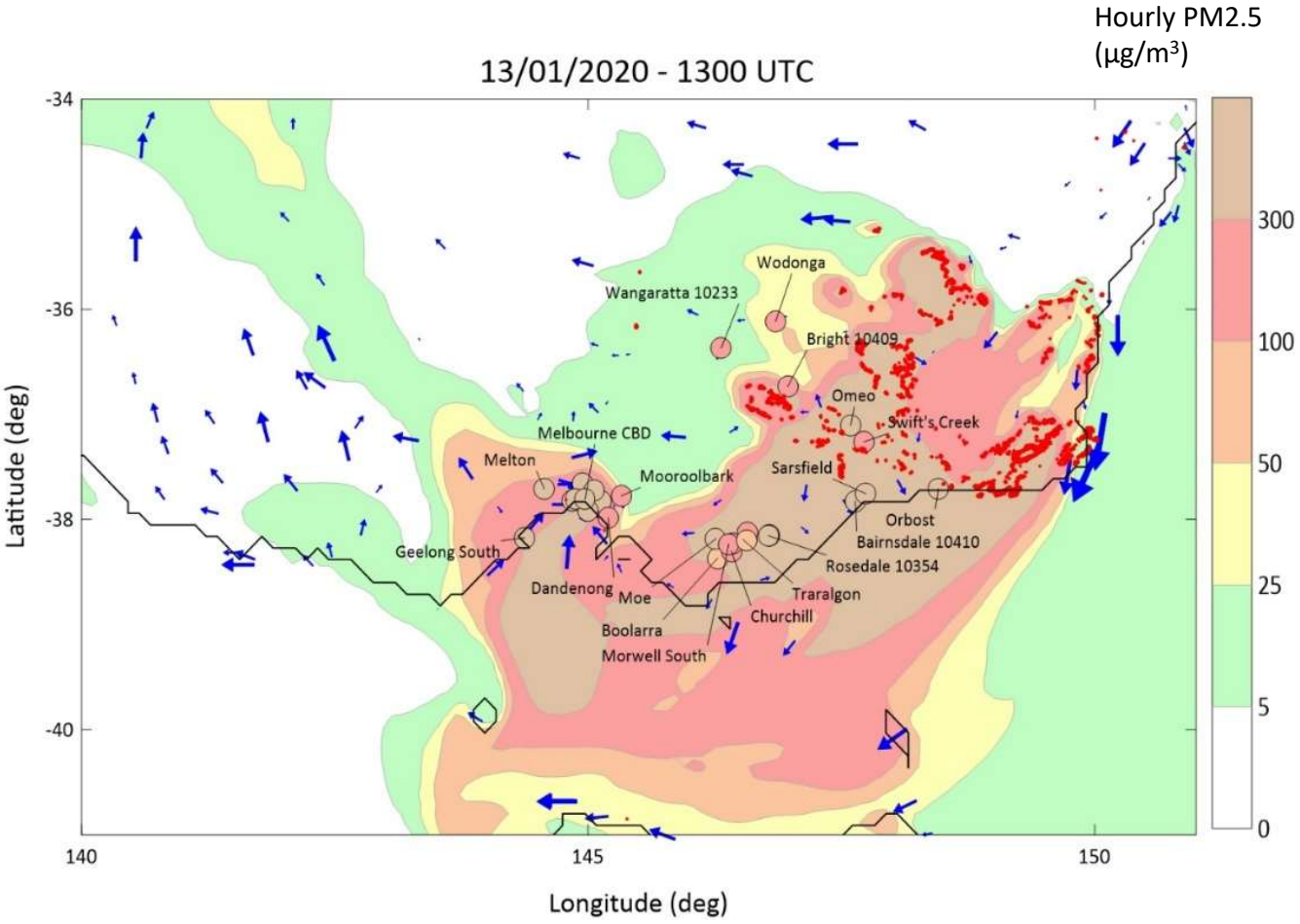
Agricultural burning across Vic/NSW picked up via the VIIRS hotspots







Major Uncertainties in Smoke Forecasts




Smoke plays havoc as Australian Open qualifier suffers coughing fit

Slovenian Dalila Jakupovic suffers breathing difficulties
Match at Kooyong involving Maria Sharapova abandoned

Source: The Guardian (14th Jan 2020)

- Complicated wind patterns which can affect the onset and duration of smoke events
- Timely identification and location of fires
- Complexity and variability in fuel loads and fuel consumption
- Temporal distribution of emissions
- Plume rise which affects smoke plume dispersion

How do we minimise the uncertainties?

- Complicated wind patterns
- Timely identification and location of fires
- Complexity and variability in emissions

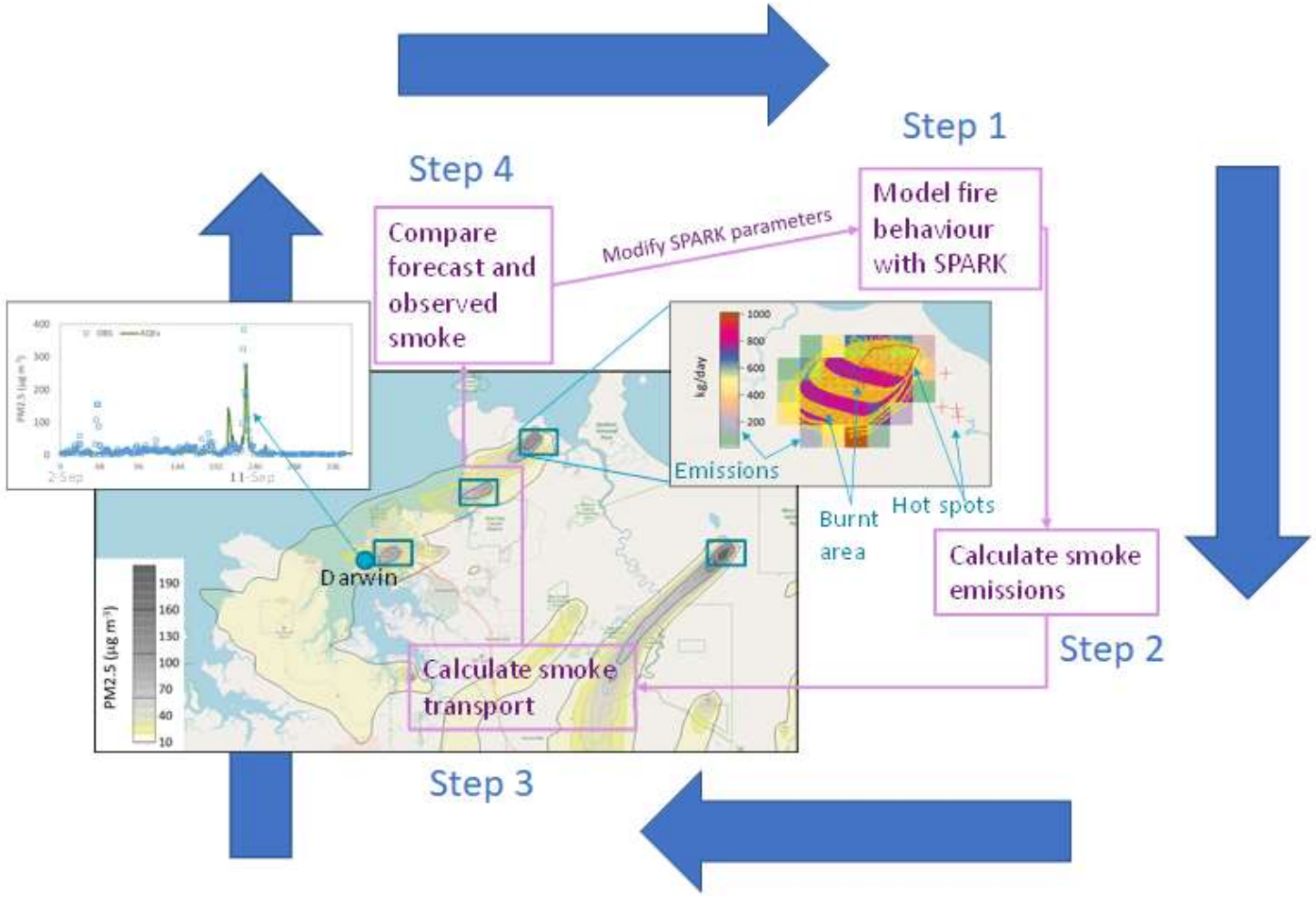
Data Assimilation

Ensemble forecast

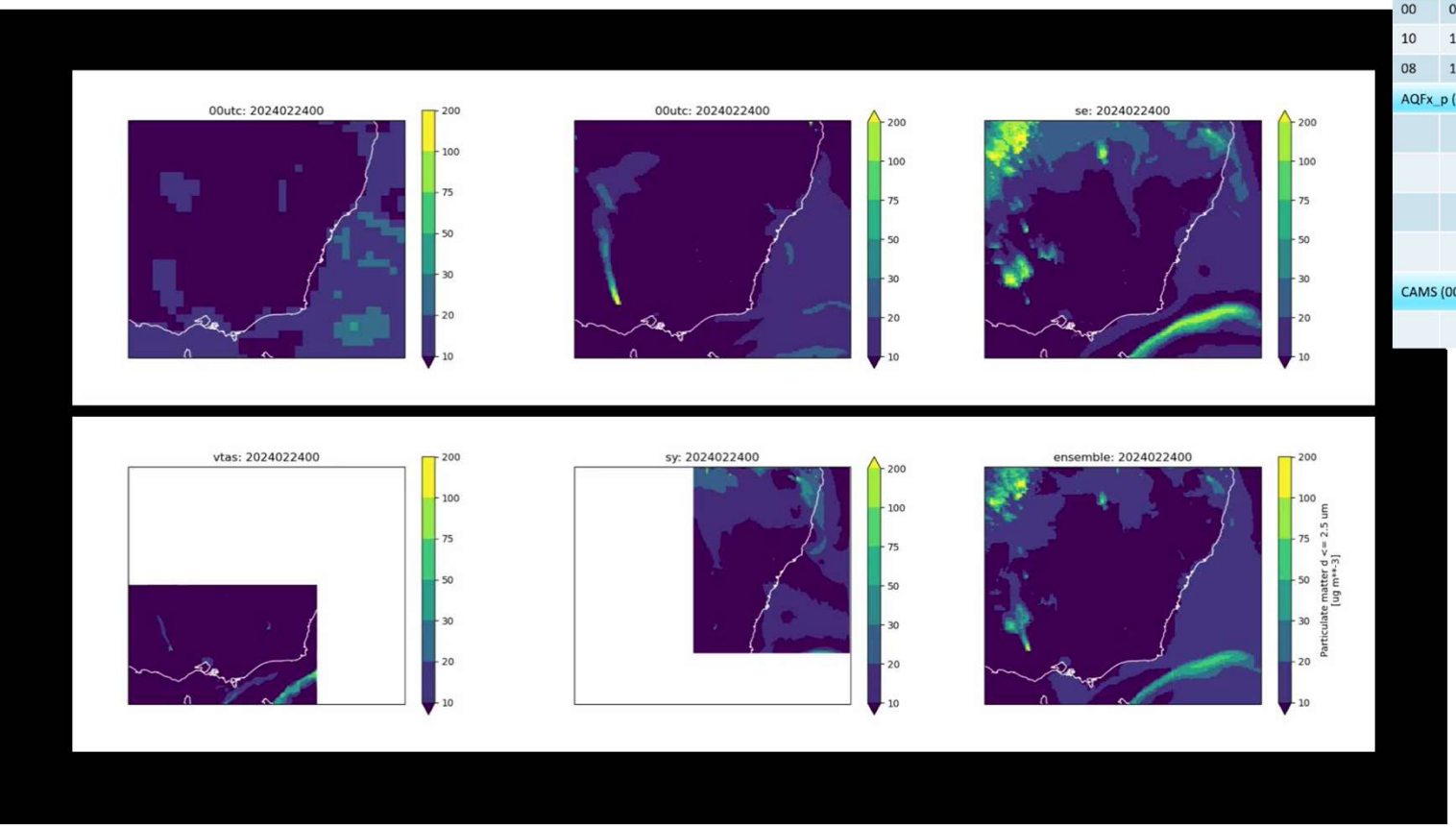
Rapid Update Cycle forecast

Evaluation and Validation

Data Assimilation - improve the uncertain parameters and the initial conditions



Ensemble Forecasting – indication of the robustness of the forecasts

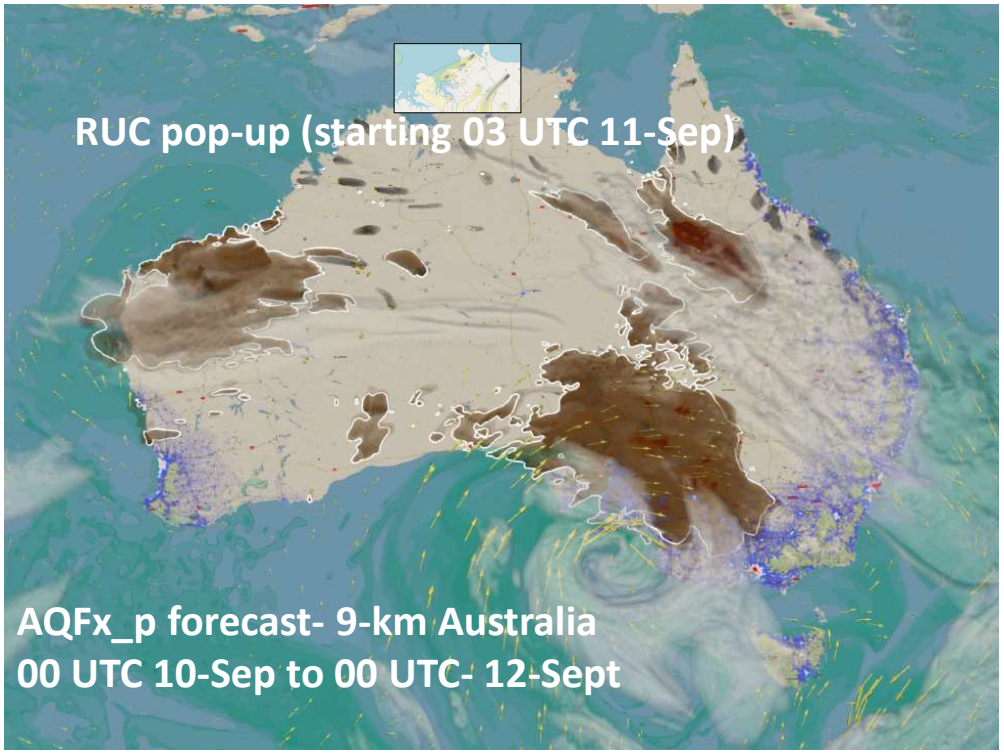


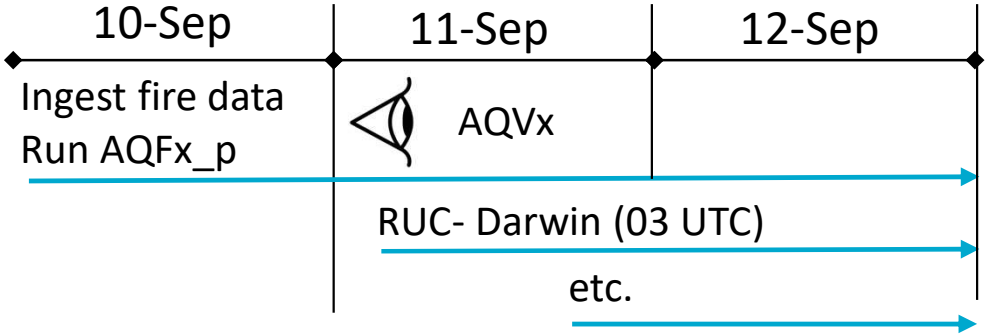
Forecast generation- day 0				Forecast- day 1				Forecast- day 2				Forecast- day 3			
00	06	12	18	00	06	12	18	00	06	12	18	00	06	12	UTC
10	16	22	04	10	16	22	04	10	16	22	04	10	16	22	EST
08	14	20	02	08	14	20	02	08	14	20	02	08	14	20	WST
AQFx_p (00UTC)															
			AQFx_p (18UTC)												
				ASDS-SE											
				ASDS-VTAS											
				ASDS-SY											
CAMS (00UTC)															
		CAMS (12UTC)													

- Focus initially on $PM_{2.5}$, extended to include AOD.
- Investigate the use of weighting factors to improve the ensemble accuracy.

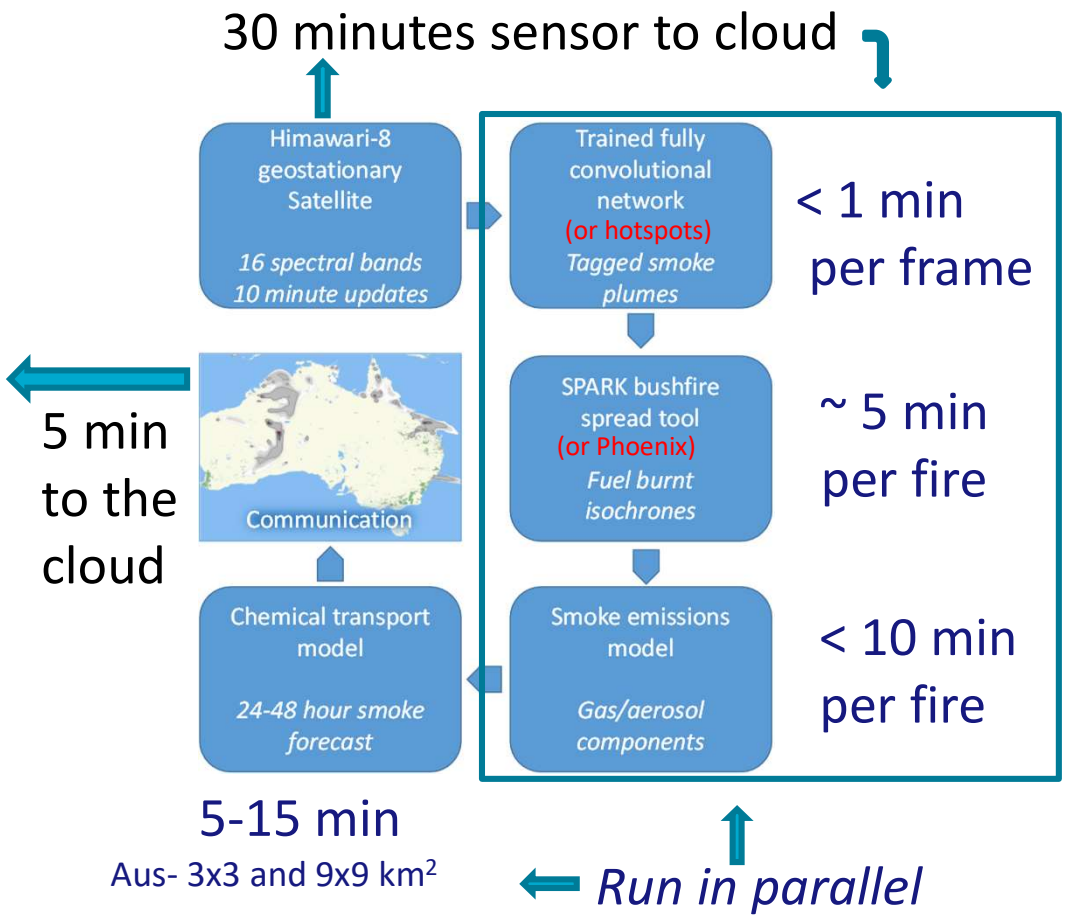
Makkaroon et al (2023). Development and Evaluation of a North America Ensemble Wildfire Air Quality Forecast: Initial Application to the 202 Western United States 'Gigafire'. JGR-Atmospheres, 128, e2022JD037298.

Rapid Update Cycle Forecasts



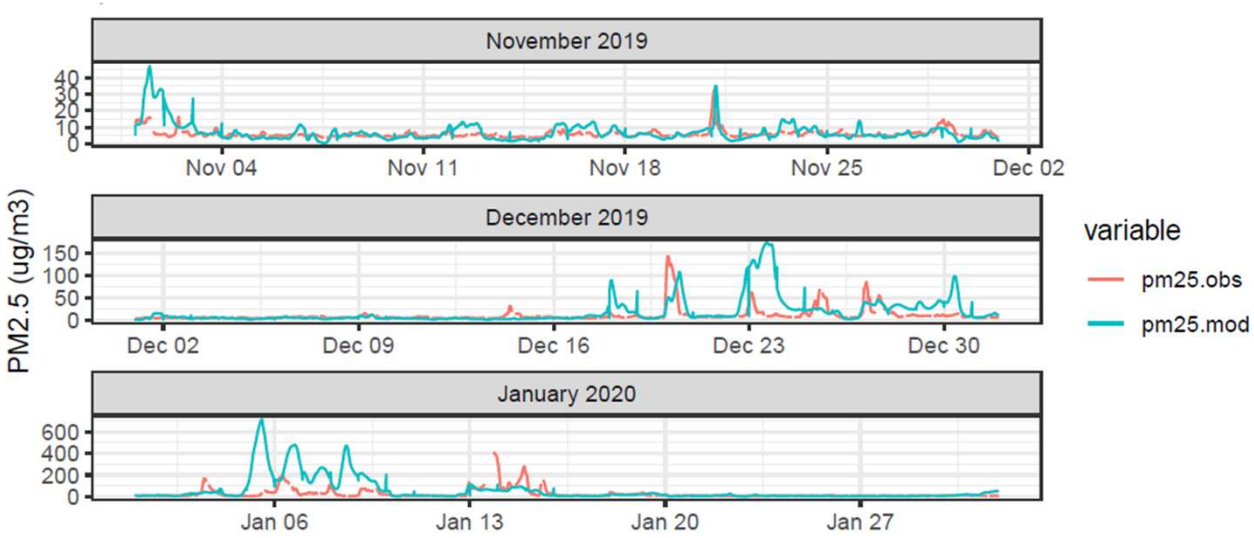


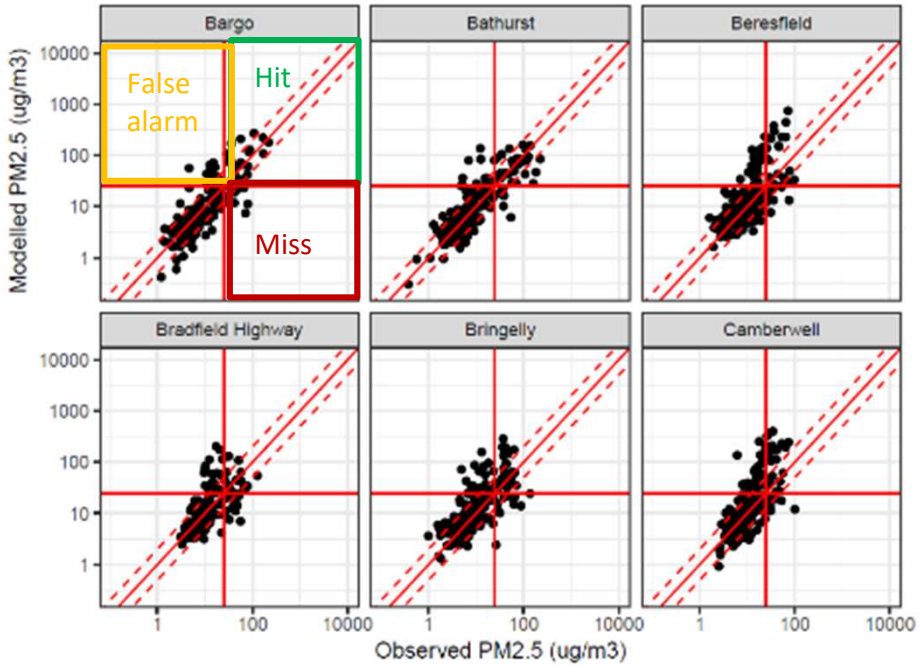
Hourly RUC- goal: an updated AQ forecast issued within 1-2 h of a full disk scan by Himawari-9



Evaluation and validation - AQEx package

Time series plots - how well does the model capture the onset, the duration, and the magnitude of smoke plume events.

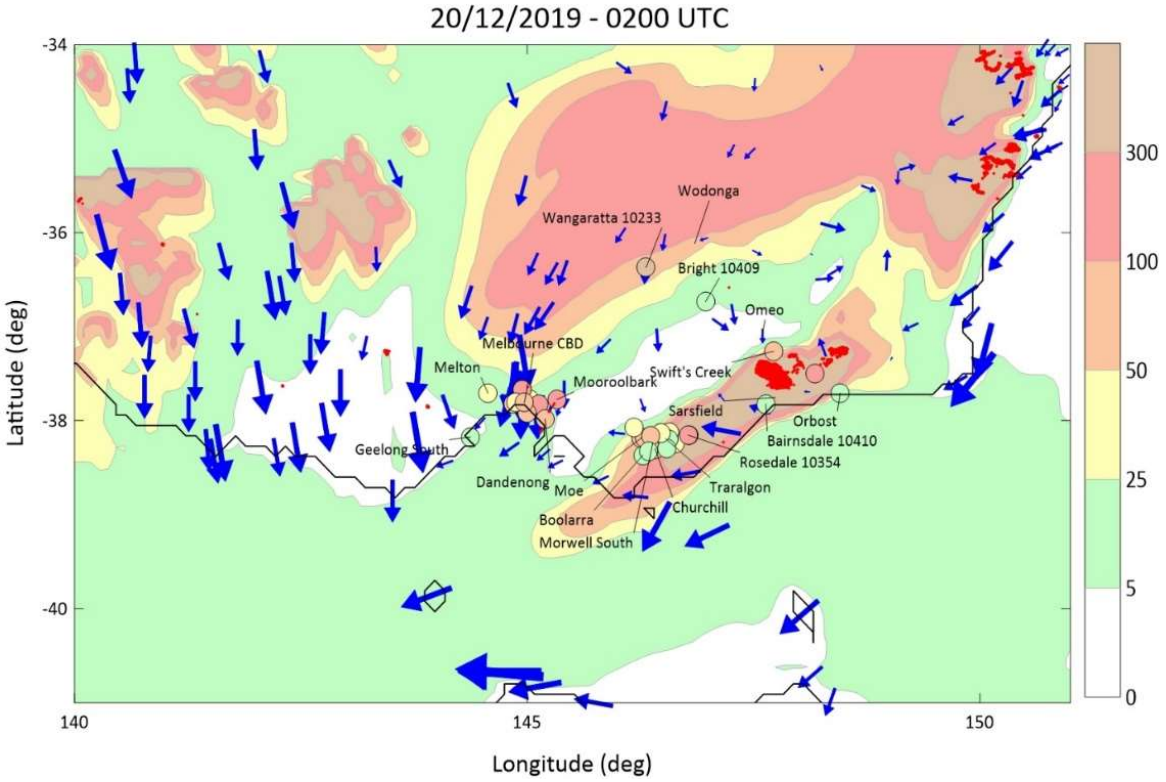




Scatter plots compare the modelled and observed 1-h and 24-h PM2.5 concentrations - indicate whether an exceedance was captured, missed or falsely identified.

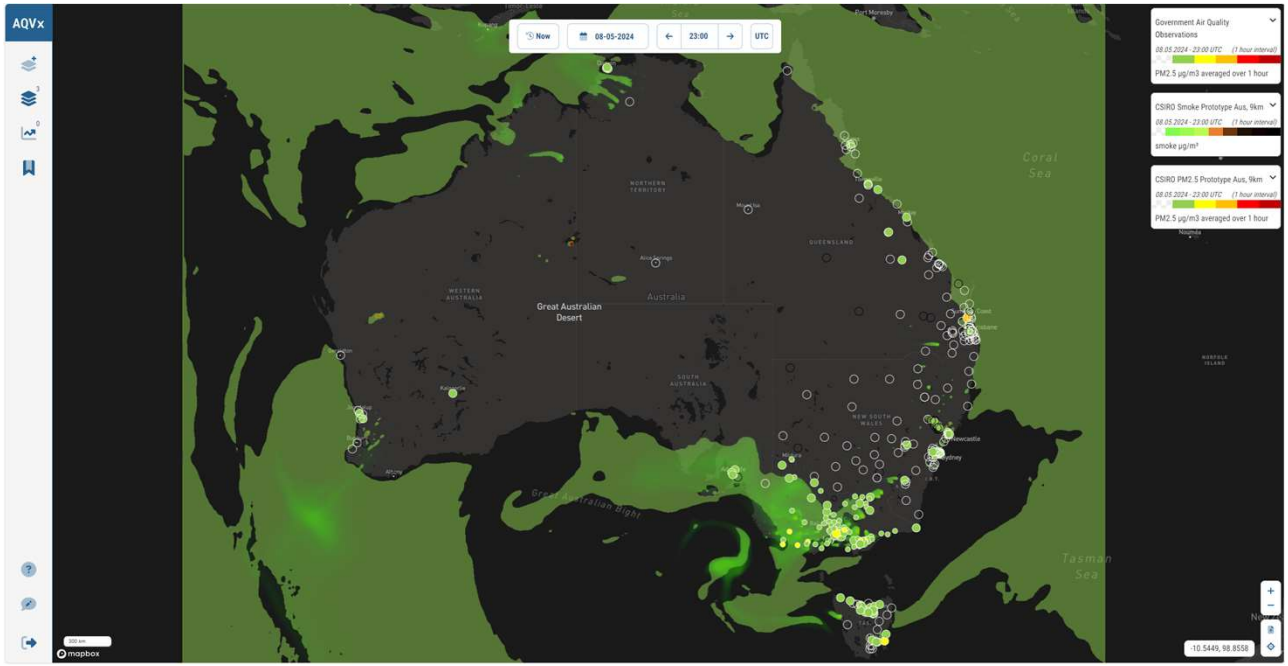
Visual Plume Assessment

Victorian Alps forming a physical barrier to the smoke plumes from fires in the north and south of Victoria



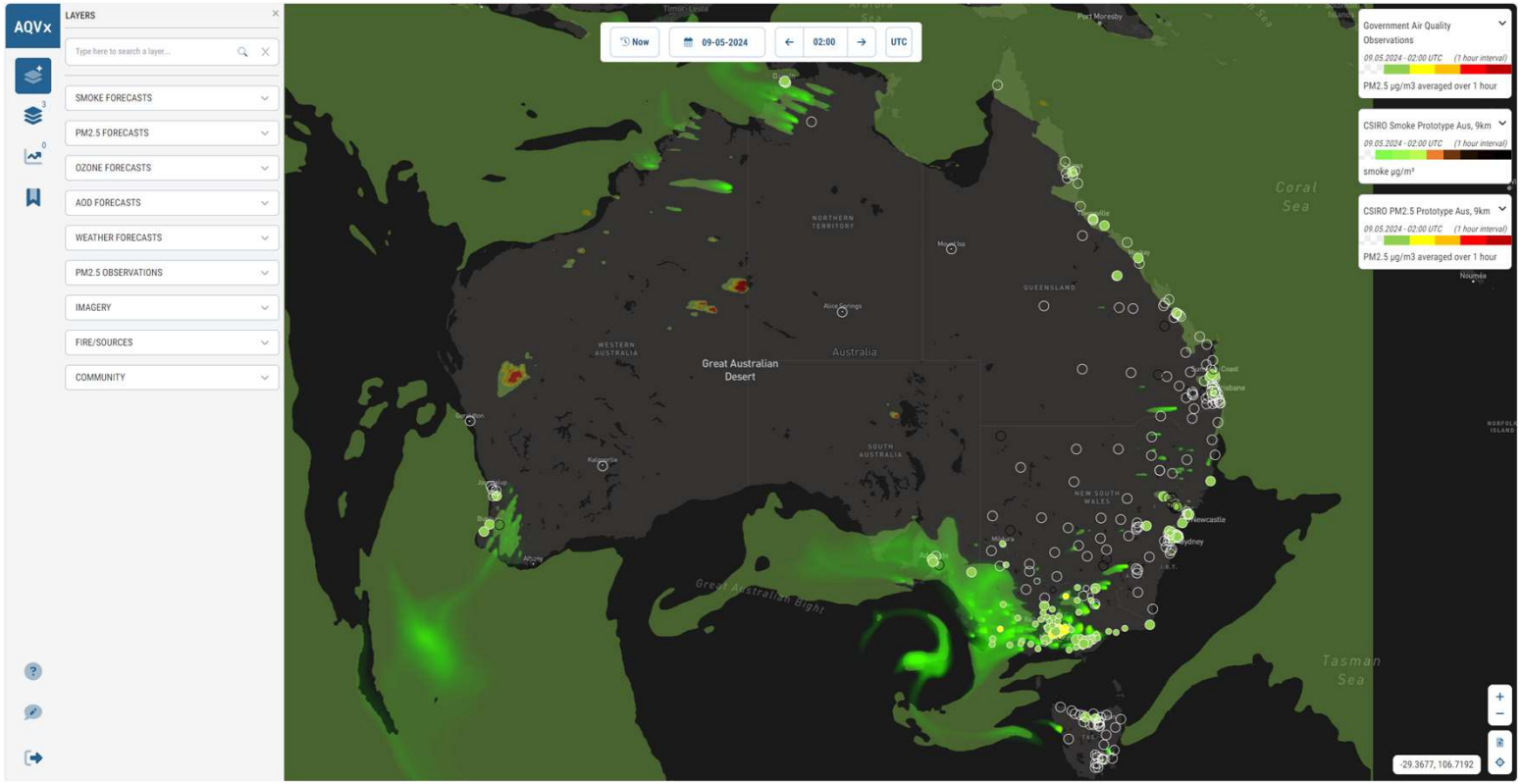
Air Quality Visualisation Platform AQVx

Aim is to provide robust, accurate, timely and nationally consistent air quality (including smoke and dust) forecasts in a user-friendly and intuitive visualisation platform that informs situational awareness and is optimised for stakeholder applications.



- Current warnings and community advice of when smoke will impact communities.
- Scenario planning with rapid estimation of at-risk exposure.
- Impact modelling of identified high risk areas.

Layers in AQVx



Modelled layers

ASDS – Bureau's operational forecast system

AQFx_p –CSIRO's national prototype system

Ensemble – weighted averaged data from multiple model outputs

Rapid Update – hourly updated forecasts triggered by the detection of new fires

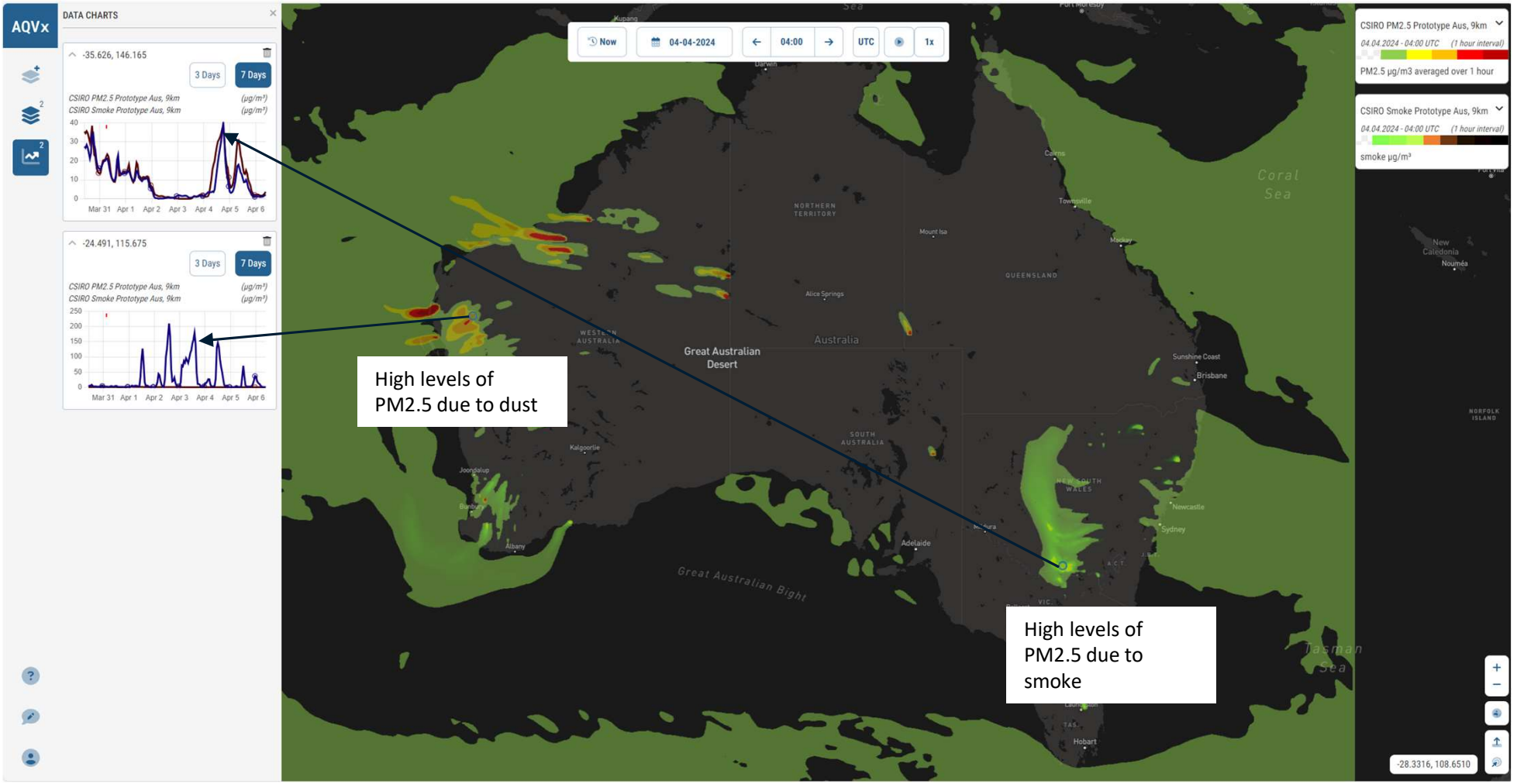
Lofted – Smoke present above boundary layer

PM2.5, smoke and ozone contour plots of ground-based concentrations.

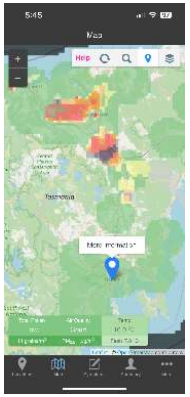
PM2.5 = smoke + anthropogenic (e.g., urban, transport, industry) & biogenic sources (e.g., dust)

Smoke = fraction of PM2.5 that is due to smoke

Distinction between smoke and dust



Symptom reports from the AirRater app



Thank you

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