When Dust Meets Cloud: Overcoming Satellite Monitoring Gaps in High-Impact Pollution Events Across Australasia

Himawari, Dust Storms, Cloud Masking, Air Quality, Satellite Aerosol Monitoring, CAMS Reanalysis

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Abstract

Wildfire, dust, and haze events across Australia and Southeast Asia evade satellite detection due to surface reflectance and cloud cover. In 2019, Australia experienced record dust storms while Southeast Asia faced severe haze from peat fires and post-monsoonal stagnation. Standard AOD products (MODIS, MIACC, Himawari) fail under these conditions, misclassifying aerosols or masking them entirely. This study fuses Himawari Level 1b imagery (***500 m, 10-min***) with ***CAMS*** [2] reanalysis to enhance spatial-temporal detection and provide chemical context and coarse quantification. These climatic events reflect a ***climate-energy imbalance*** driven by stronger thermal gradients, persistent high-pressure systems, and accelerated ***Lorenz-cycle*** transitions.

Current Limitations

- **Bright land masks dust**
- **Cloud cover obscures smoke and haze**
- **Aerosol types poorly resolved**
- **Key bands excluded from AOD calculations**
- **Resolution too coarse for events**
- **Dispersion models miss peak episodes**
- **Sparse downwind monitoring**

Methods Overview

- Upscale to 500m using red shift (daytime) [3]
- Normalise Brightness Temperature (±1)
- Calculate BTD indices [4],
  heat-to-motion shifts = driving climate dynamics.
  - ❖ $BTD_{07–08}$ → Fire Hotspots
  - ❖ $BTD_{10–09}$ → Vertical Stability
  - ❖ $BTD_{04–15}$ → Particle Size
  - ❖ $BTD_{13–11}$ → Aerosol vs Gas
  - ❖ $BTD_{02–16}$ → Gas Signatures
- Classify **20 AIR TYPES** via binary BTD logic
- IR transparency reduce clouds **~50% to ~5%**
- Estimate WS dispersion via
  Conc ∝ WS ∝ ∇MSLP ∝ $\Delta T_{10–9}$
- Calibrate with CAMS Reanalysis to GLC's

Case Studies (2019)

- Kalimantan Fires – 14 Sep 2019
- Hanoi Cloud Haze – 15 Oct 2019
- NSW Dust Storm – 22 Nov 2019
- Black Summer Fires – 10 Dec 2019

Conclusions

- Assess BoD via Δr–NBT and BTD indices
- Applied to SE Asia + Australia (fire, haze, dust)
- 10-minute intervals, enables near real-time
- CAMS calibration offers coarse baseline
- Differentiation evident, further work to quantify

Policy Implications

- Daily calibration via monitoring and reanalysis
- Focus on change detection & meteorological drivers
- Parallel workflows to match satellite cadence
- Infrared BTD replaces AOD cloud masking
- Full GLC's incl PM_1, $PM_{2.5}$, PM_{10}, NO_x, SO_2, O_3

References (DOI's)

1. Schmit 2018 10.15191/nwajom.2018.0604
2. CAMS RA (EAC4) 10.24381/d58bbf47
3. Sowden 2024 Δr-NBT 10.20944/preprints202507.1567.v1
4. Sowden 2019 BTD's 10.1016/j.atmosenv.2020.117620

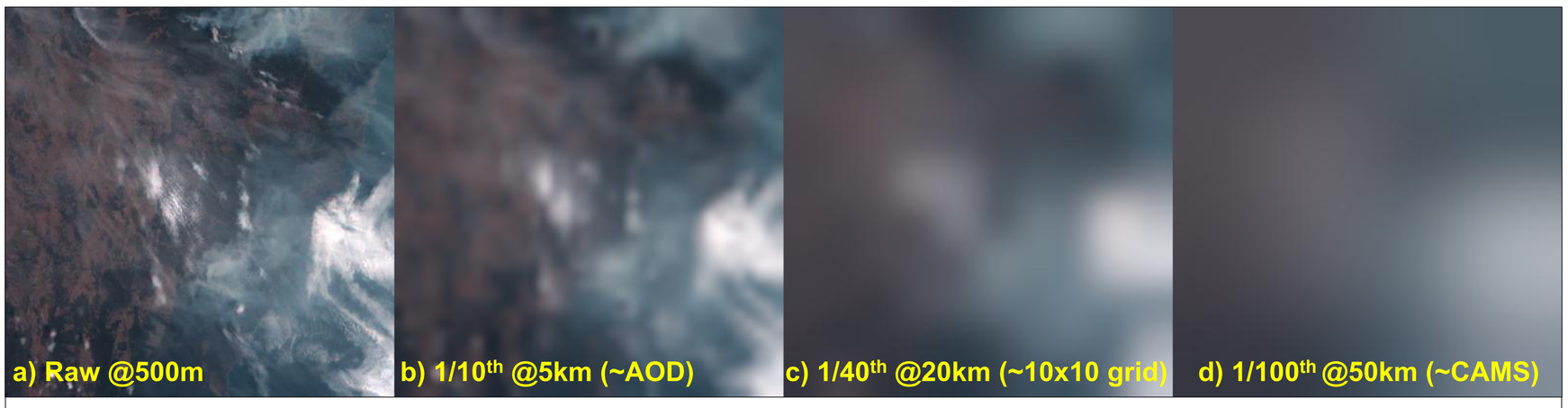

Figure 1: Resolution Disparity — 500 m vs 5 km vs 20 km vs 50 km

Band	Wavelength	Application [1] Schmit et.al 2018
1	0.471	vegetation, aerosol
2	0.51	vegetation, aerosol
3	0.639	low cloud, fog
4	0.857	vegetation, aerosol
5	1.61	cloud phase
6	2.257	particle size
7	3.885	low cloud, fog, forest fire
8	6.243	mid and upper-level moisture
9	6.941	mid-level moisture
10	7.347	mid and low-level moisture
11	8.593	cloud phase, SO_2
12	9.637	ozone content
13	10.407	cloud top, "clean longwave window"
14	11.24	cloud, sea surface temperature
15	12.381	cloud, SST, "dirty longwave window"
16	13.281	cloud top, CO_2

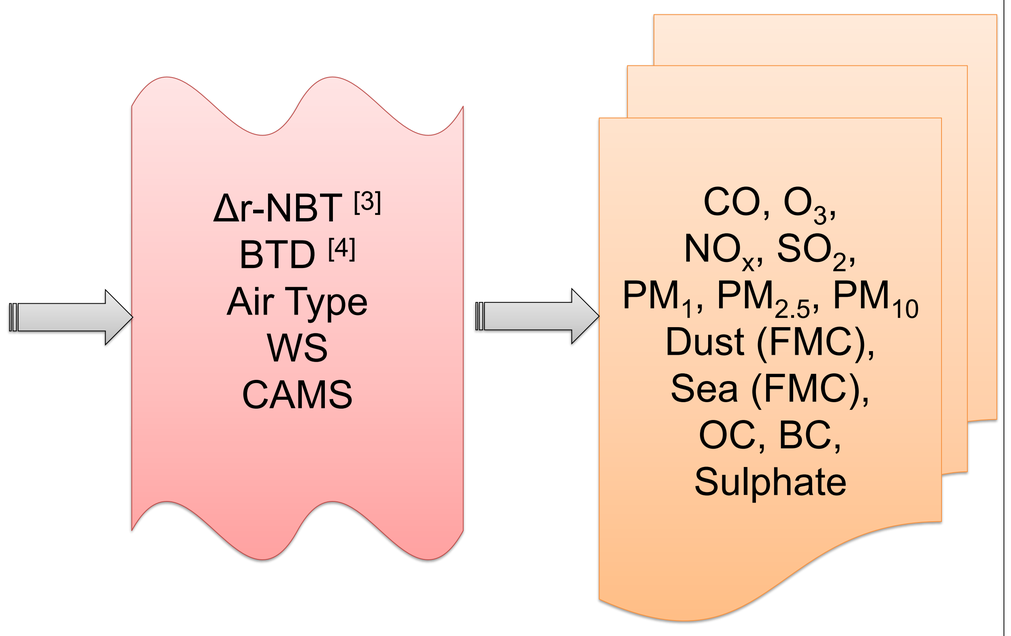

Figure 2: Himawari Retrievals → Particle Size, Speciation, Gas Composition

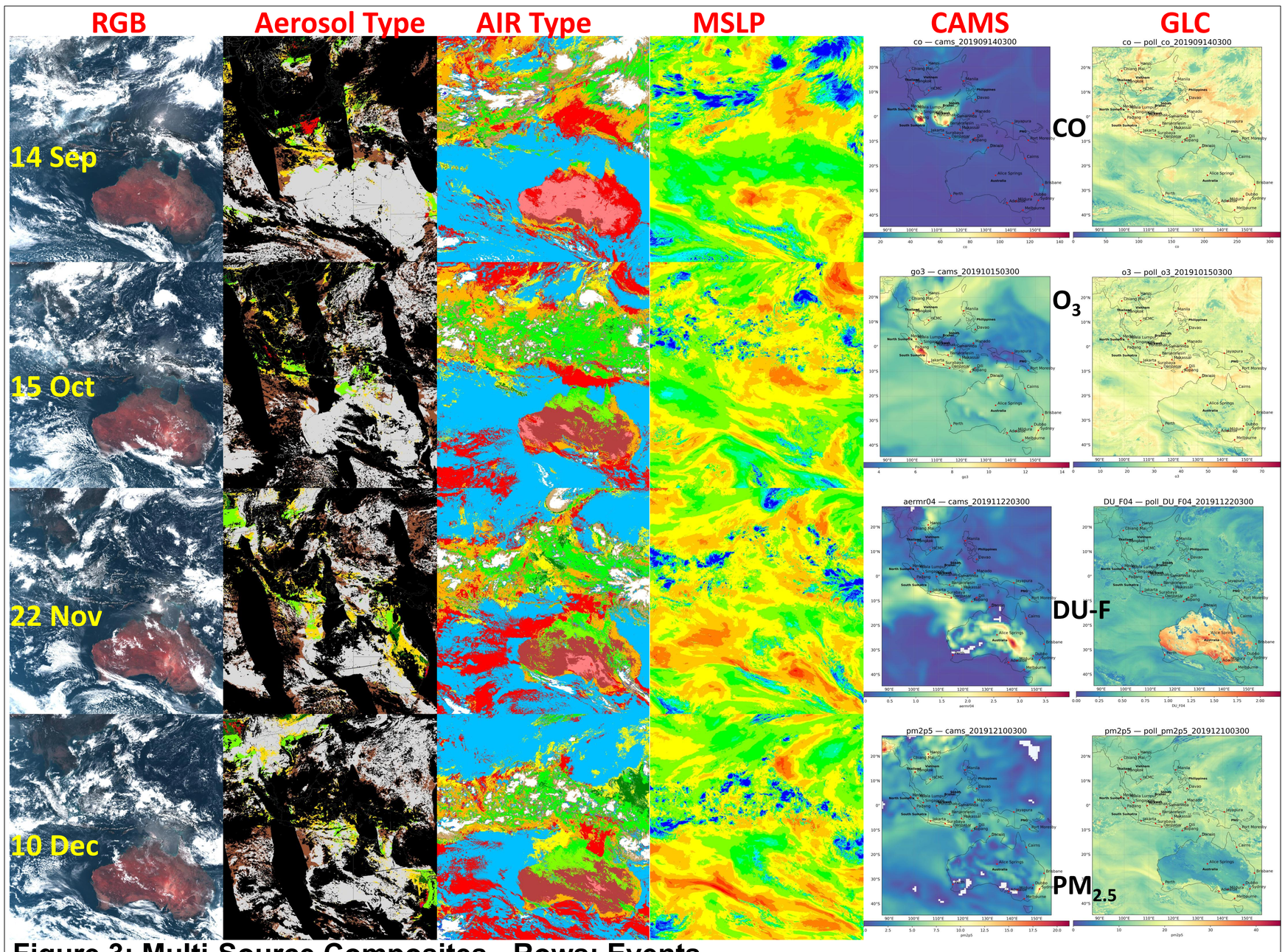

Figure 3: Multi-Source Composites - Rows: Events
Cols: Himawari RGB, MODIS Aerosol Type, Derived Air Type, MSLP, GLC CAMS & 2km

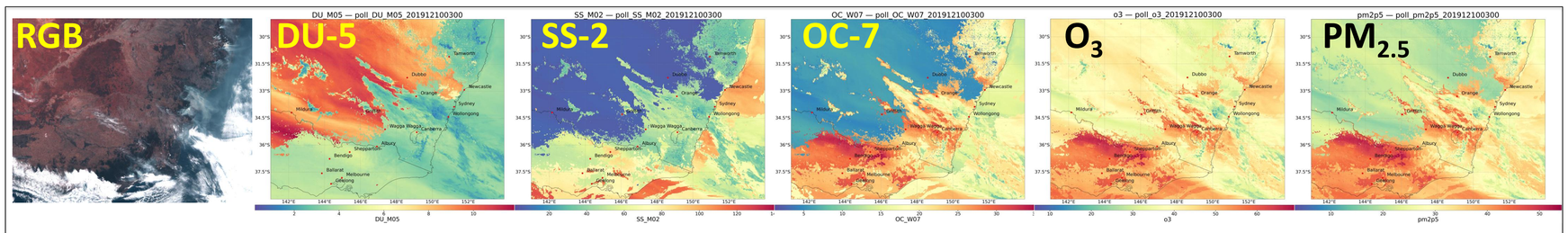

Figure 4: NSW Fires (10 Dec 2019) — 500 m Retrievals (see G7-286, 16:40, 1 Dec)
RGB, Dust <0.9µm, Sea Salt <5µm, OC, O_3, $PM_{2.5}$; species resolved under partial cloud

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