# Biomass burning at Cape Grim: using modeling to explore a possible urban influence on plume photochemistry and composition


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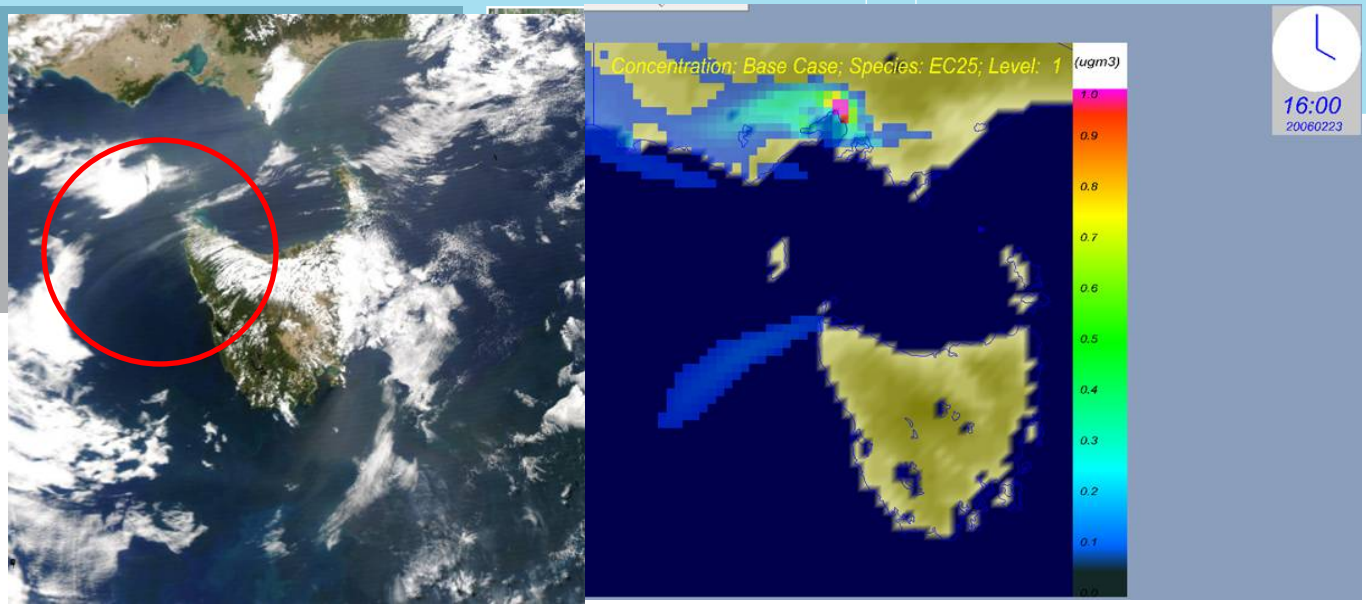



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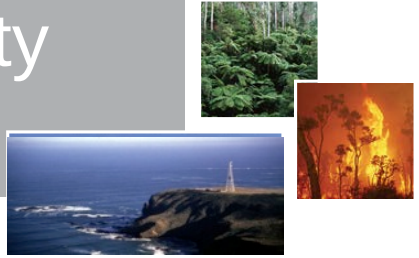
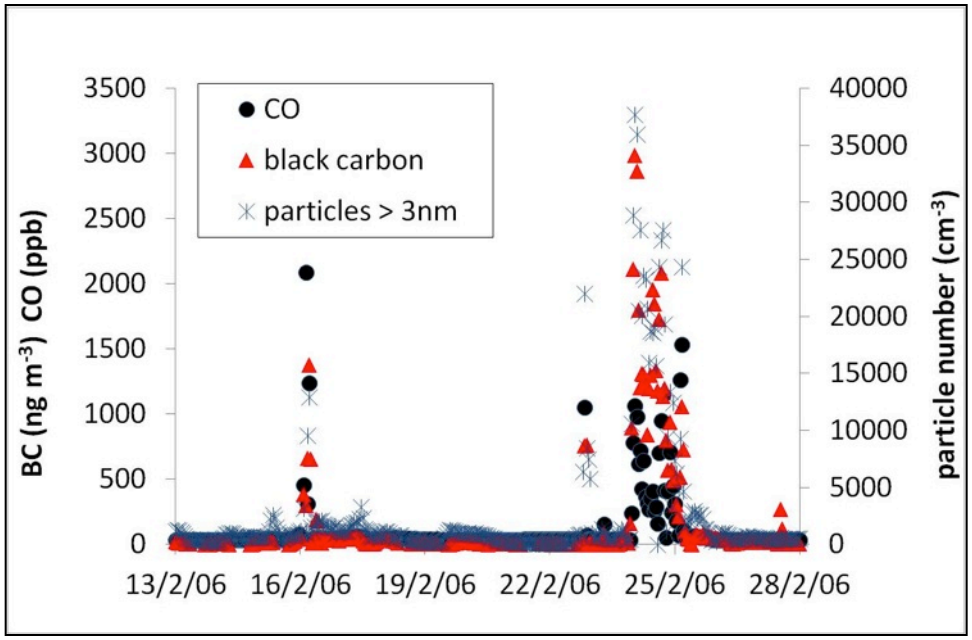
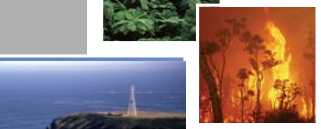
# Robbins Island fire gives unique opportunity for plume characterisation



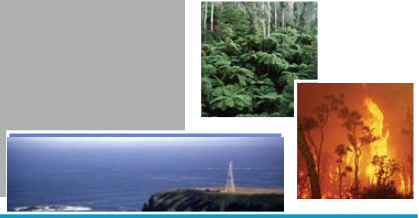




(trace gas emission ratios to CO calculated)

Wind speed ~60km hour: plume from Robbins Island takes ~20-30 min to reach Cape Grim


# Measurements – P2P campaign

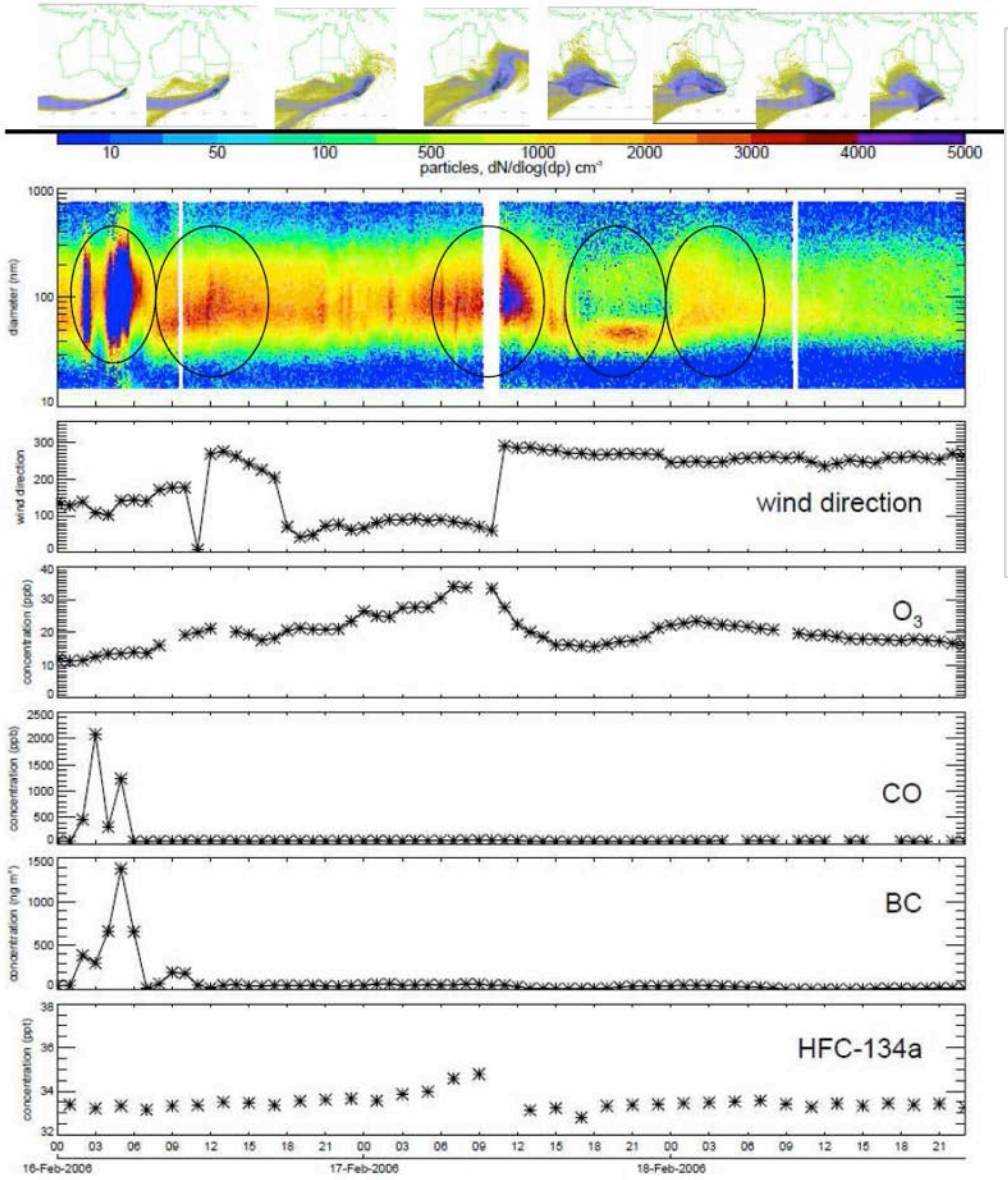


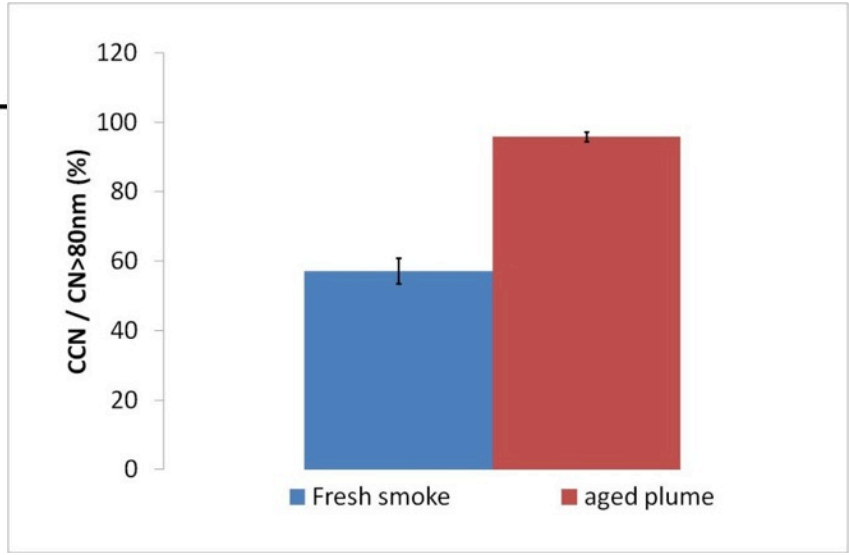
| Measurement | Instrument |
|---|---|
| Particle size distribution (14 – 700 nm) | TSI SMPS |
| Particle number >10 nm | TSI 3010 CN Counter |
| Particle number > 3 nm | TSI 3025a UCN Counter |
| Black Carbon | Aethalometer |
| Cloud Condensation Nuclei (CCN) | DMT CCN counter |
| VOCs (10 minute) | Proton Transfer Reaction –Mass Spectrometer |
| Ozone | TECO ozone analyser |
| $CH_4$ | AGAGE GC FID |
| CO, $H_2$ | AGAGE GC-MRD |
| $CO_2$ | LoFlo NDIR |
| $N_2O$ $CHCl_3$, $CH_3CCl_3$, $CCl_4$ | AGAGE GC-ECD system |
| Ethane, methyl halides | AGAGE Medusa GCMS |

No aerosol chemical composition measurements except for BC

# Different composition of fresh, aged plumes

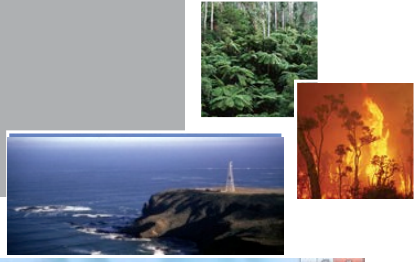





- What is driving these changes in chemcial composition?
- Fire emissions and/or emissions from Melbourne/mainland?

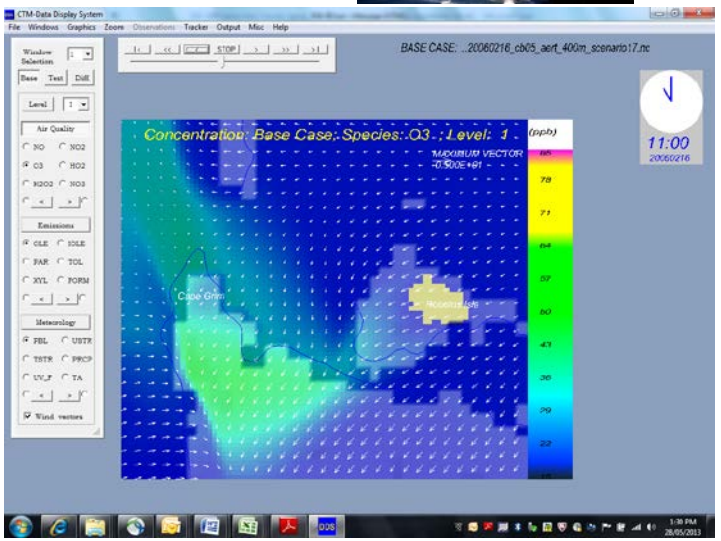
# Can modelling help determine the contribution of different sources to photochemistry, plume age?

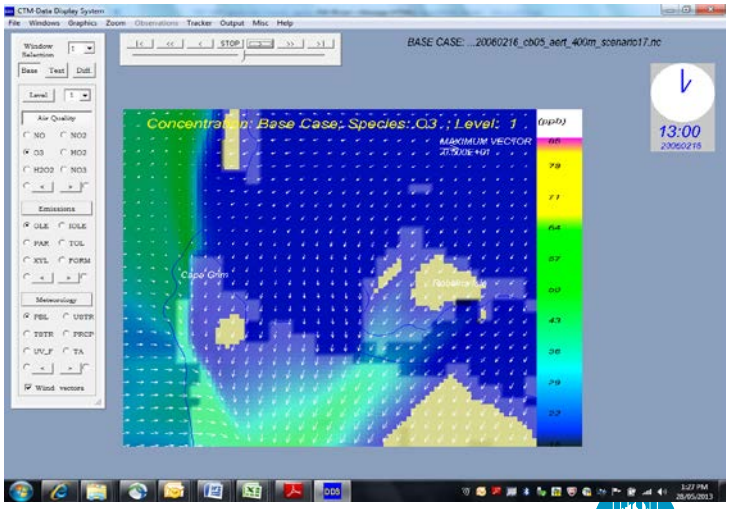


- TAPM-CTM (meteorology)
- 20km, 12km, 3km, 1km, 400m domains
- Carbon Bond 5, includes inorganic aerosol, EC, SOA
- Emissions from mainland,Tasmania (incl. fire), ocean (determine contribution from different sources)
- Fire scar used to estimate area burned

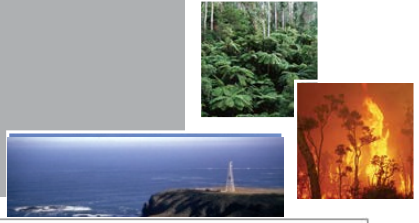
- We modified
  - boundary concentrations, diurnal emissions and plume rise

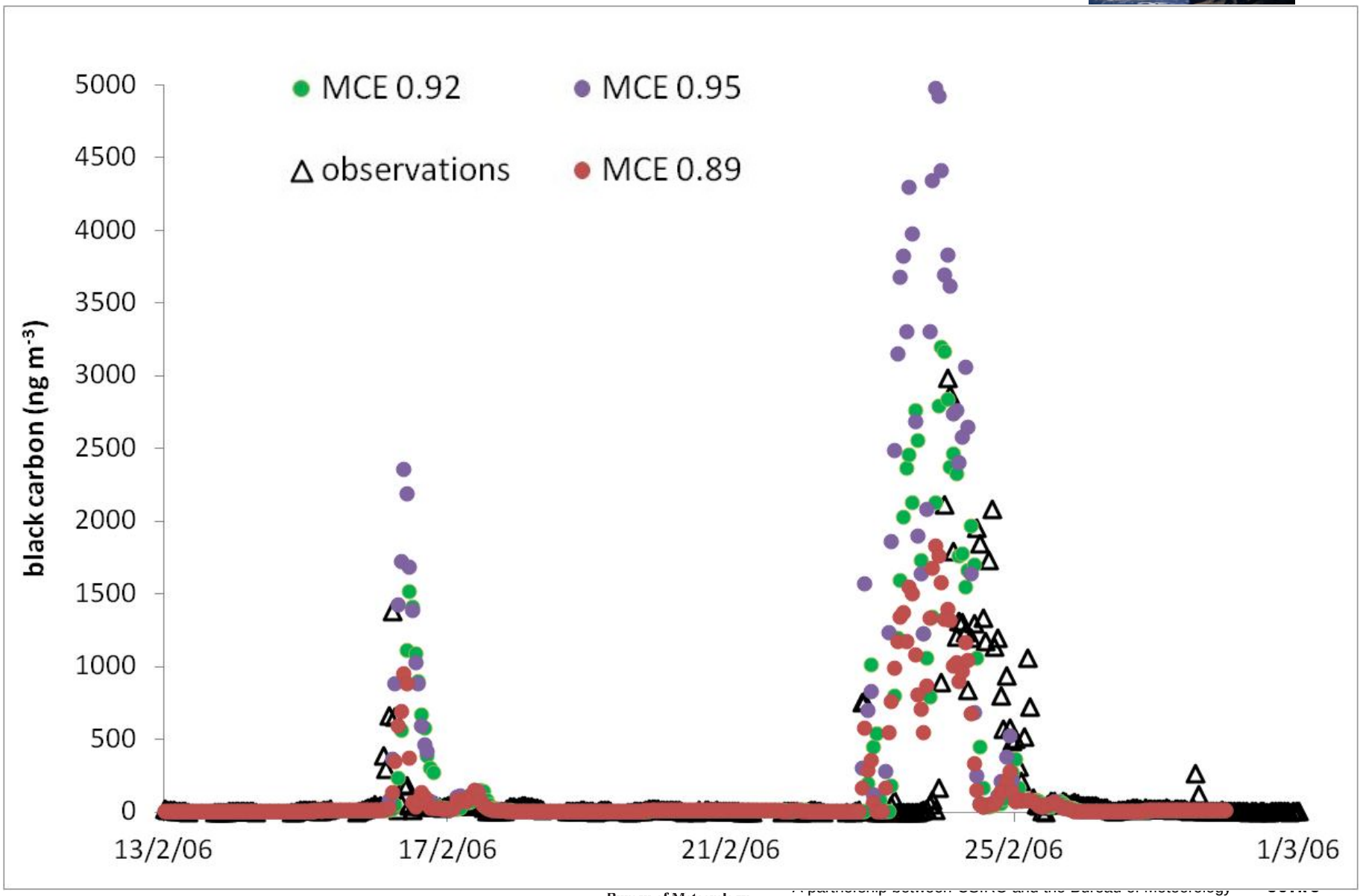
- We explored affect of
  - Changing trace gas and aerosol fire emission factors, corresponding to modified combustion efficiency (MCE) of 0.89 (lower), 0.92 (best estimate), 0.95 (upper).
  - spatial variability (1km each side of Cape Grim)



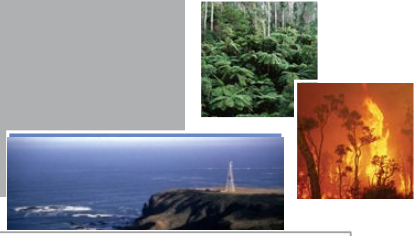



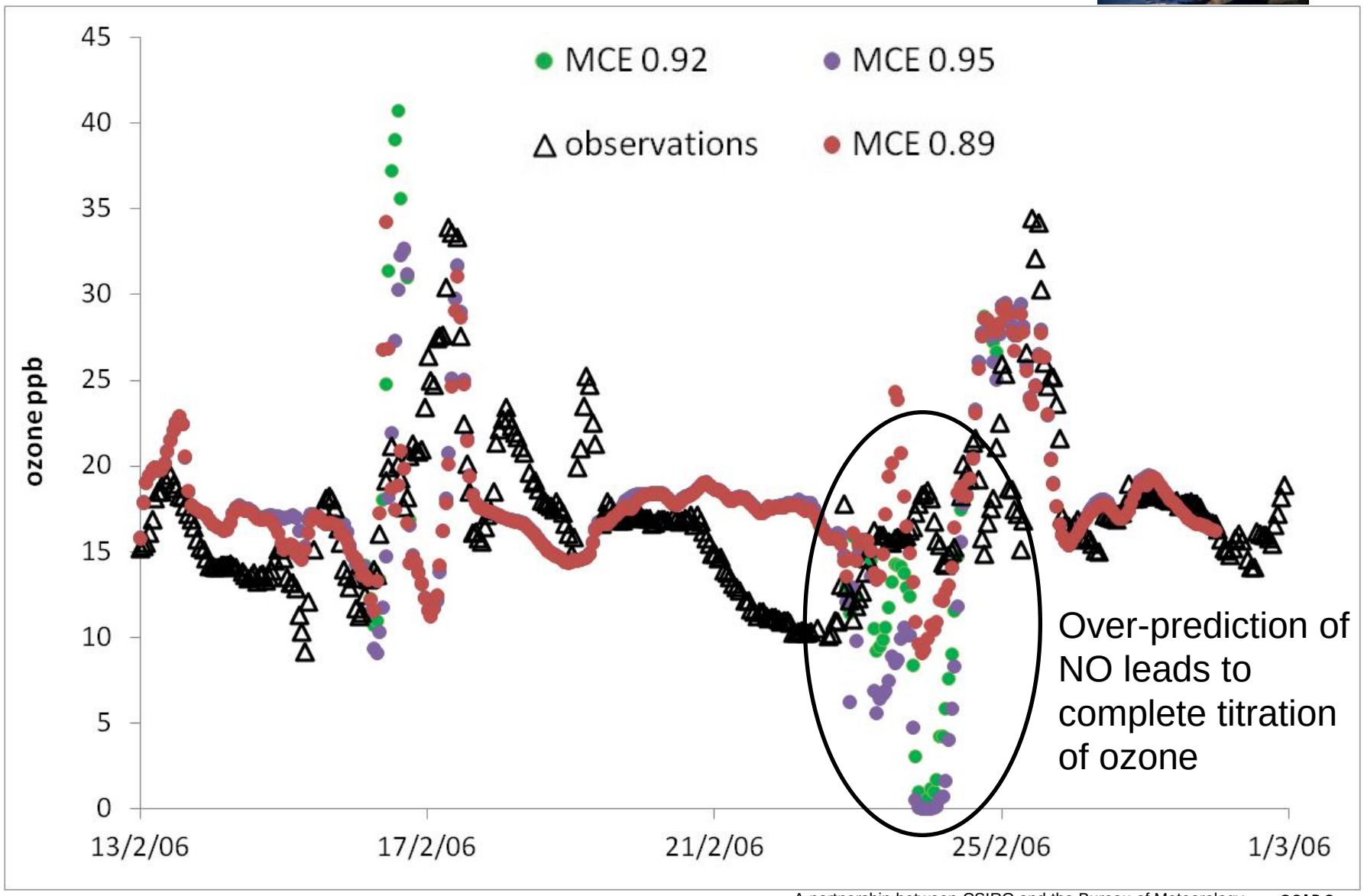
# Black carbon – modelled concentrations sensitive to emission factors



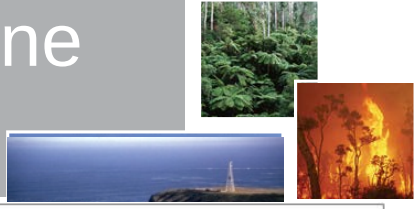


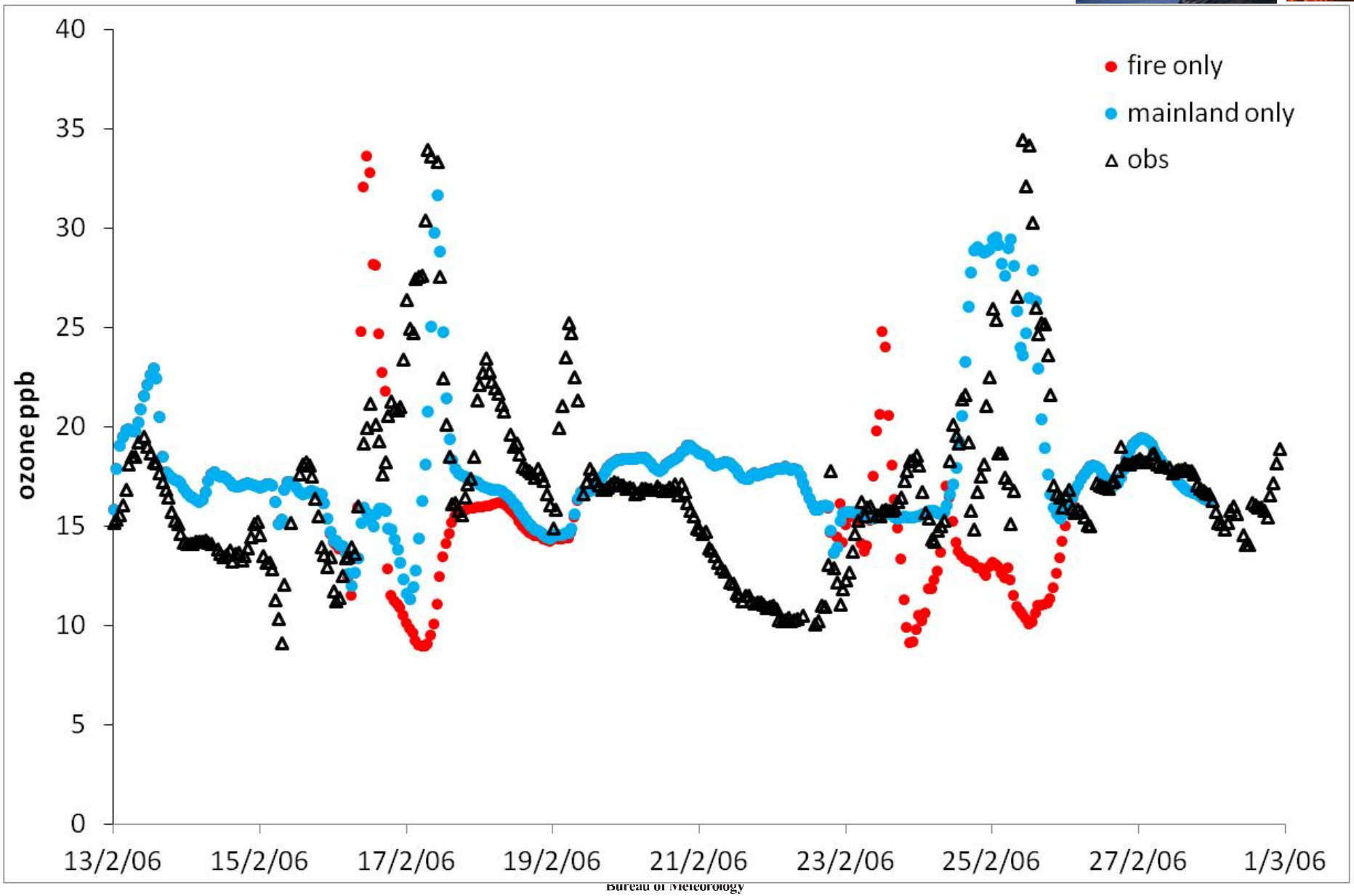
# Modelled ozone – sensitive to emission factors



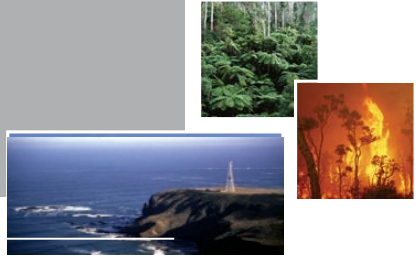


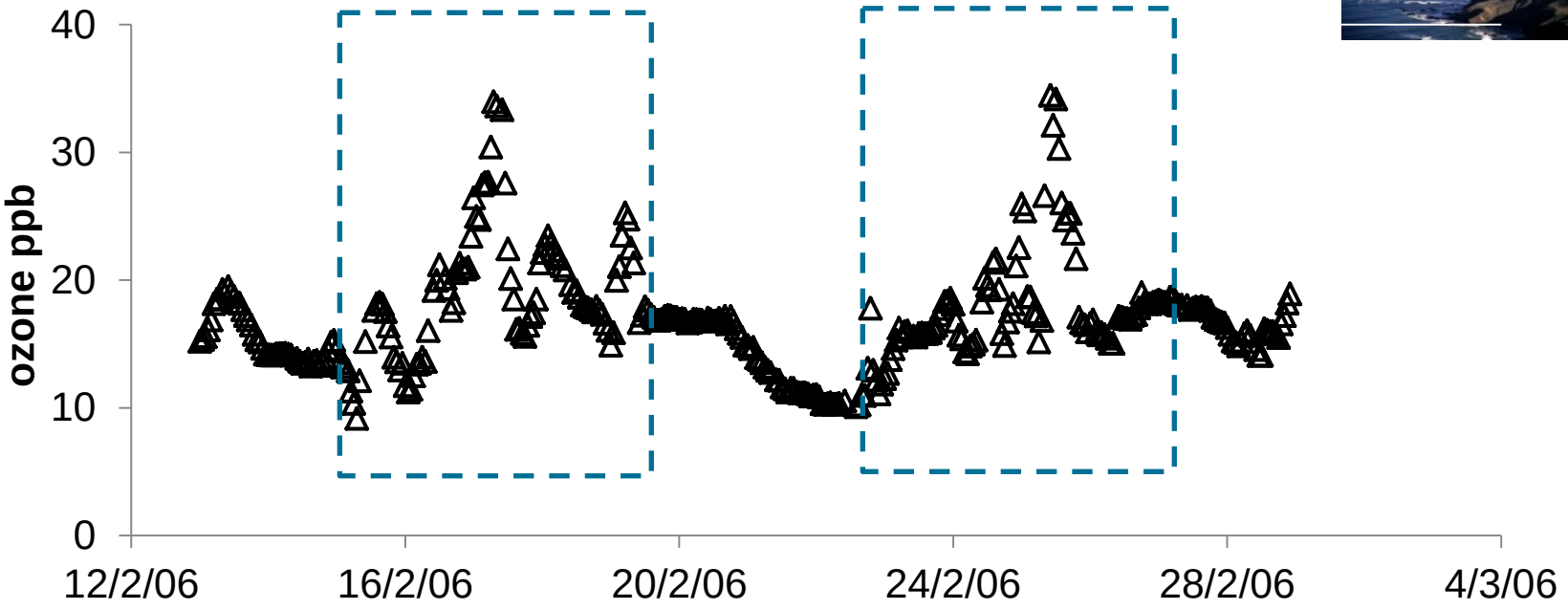
# Mainland and fire emission are driving ozone production (MCE 0.89)

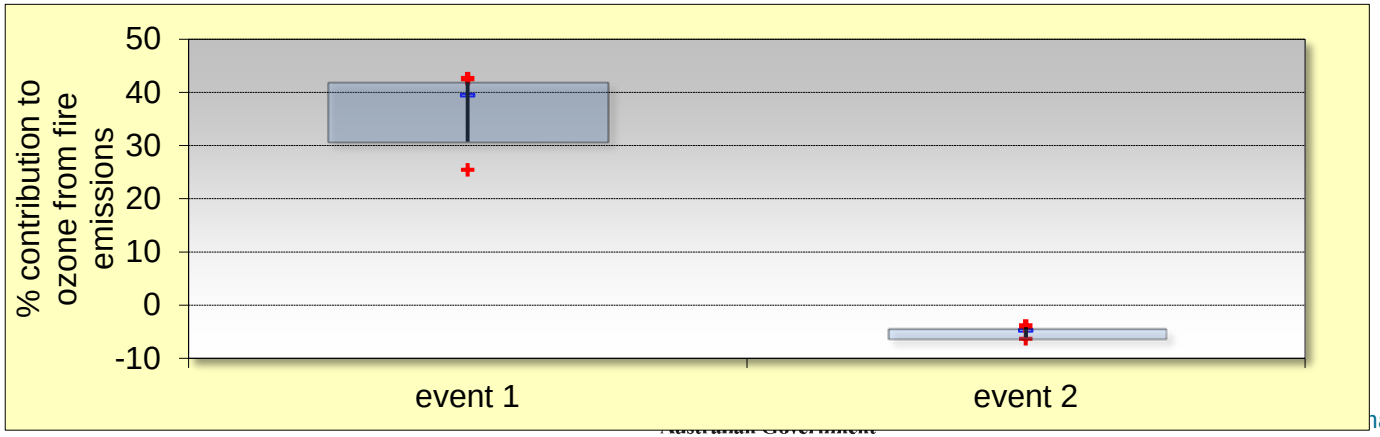




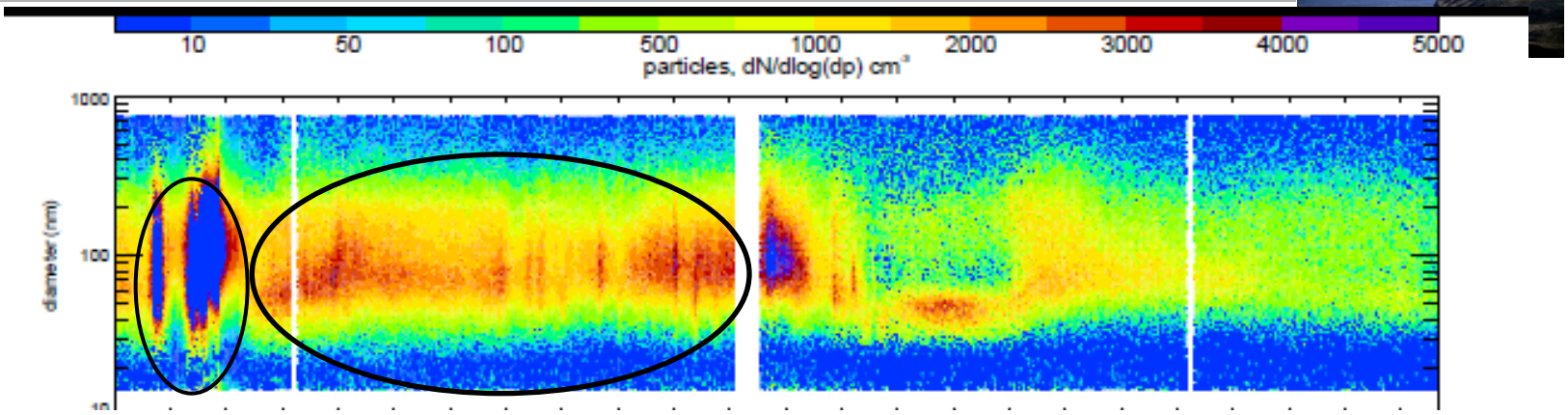
# What are relative contributions to ozone production?

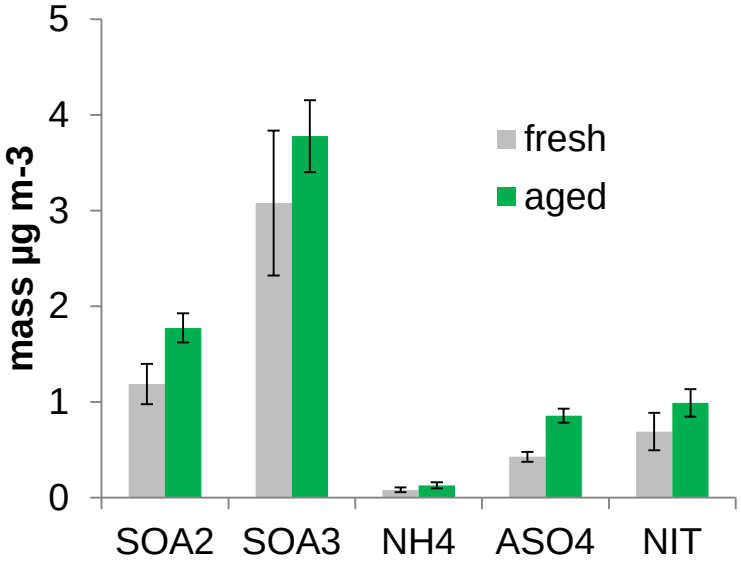


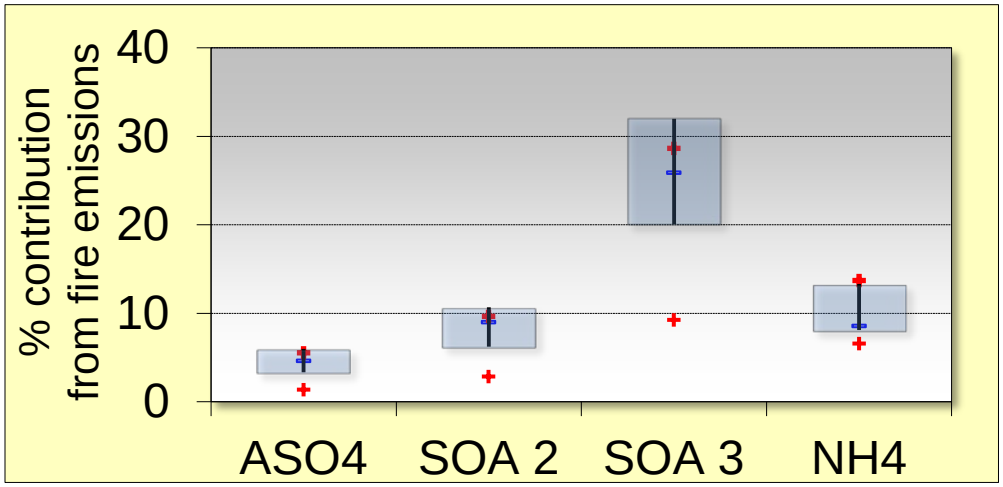


# What is driving enhanced CCN ratio in aged plume?

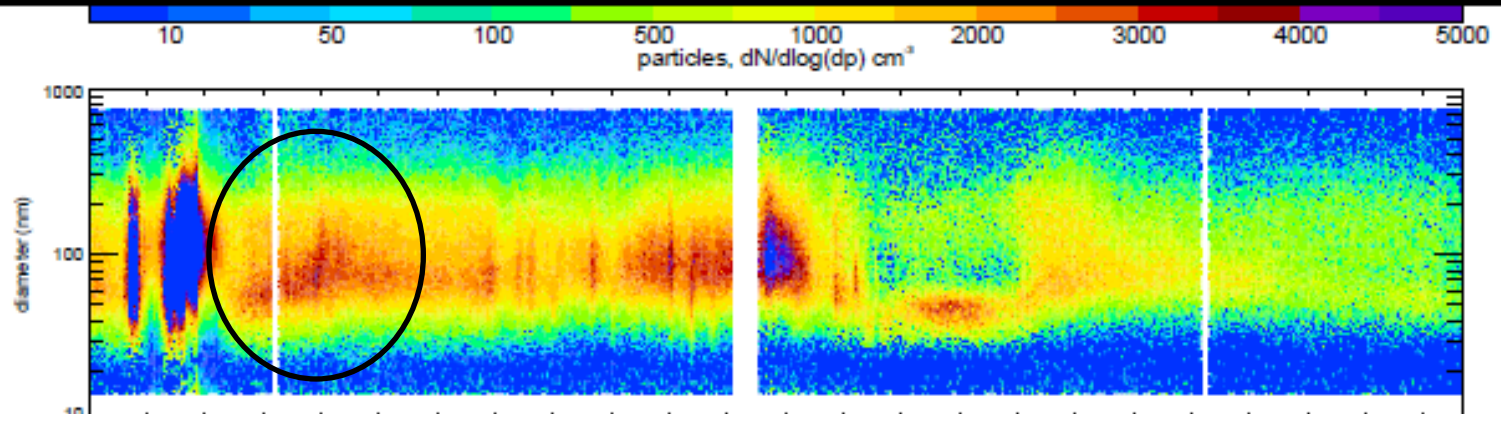


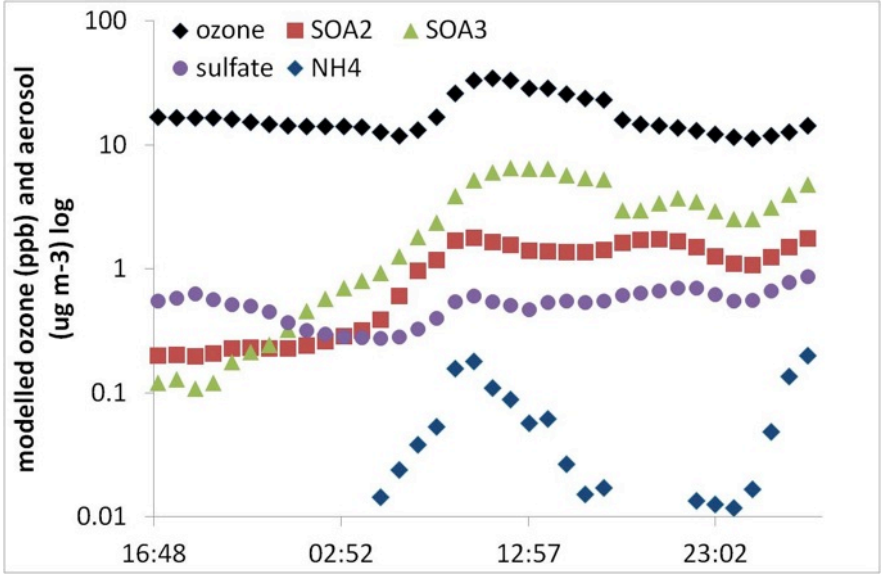



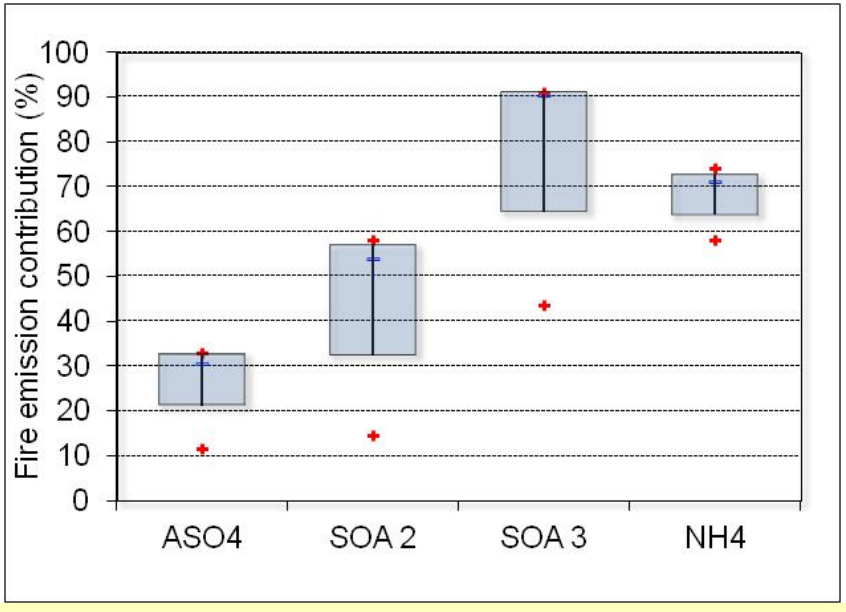




**Enhanced SOA and inorganics in aged plume likely responsible for increased CCN activity (mainly from mainland emissions)**

# What is driving particle growth event?



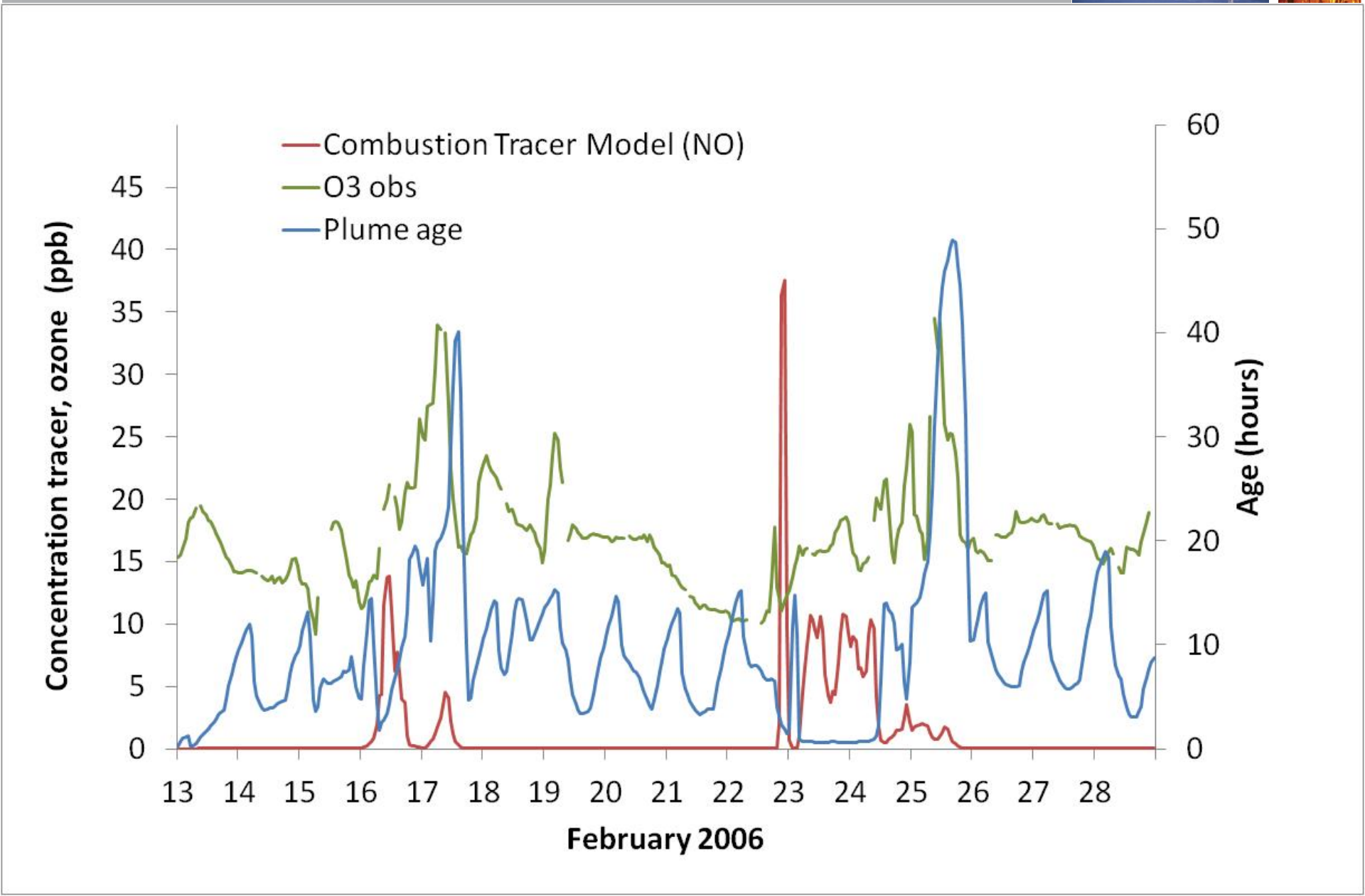



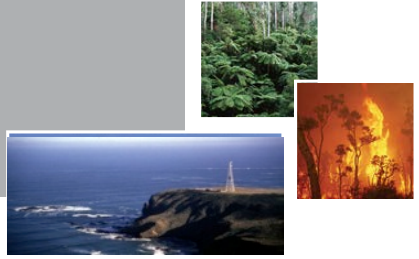

**Mainland urban emissions and fire emissions make equal contribution to particle growth event**

**…….(size resolved number and composition GLOMAP model runs to come)**

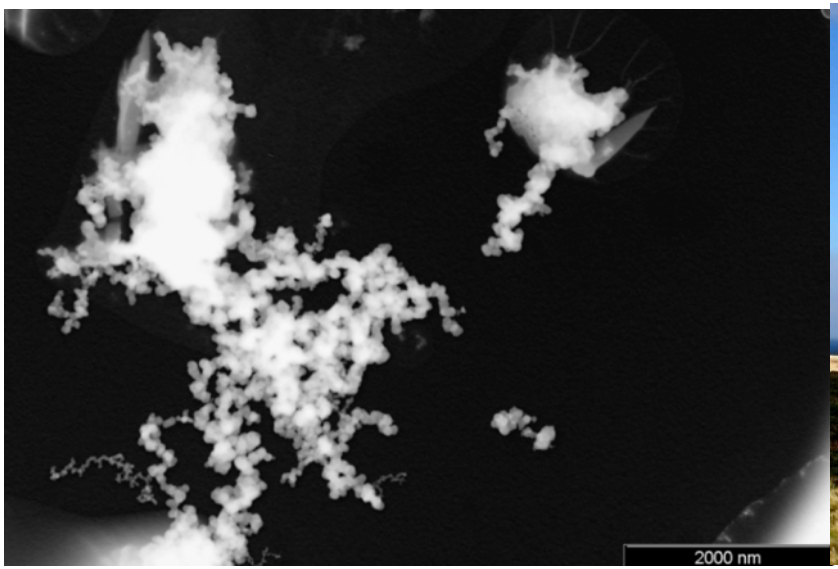
# Model predicts plume age ~ 2 days

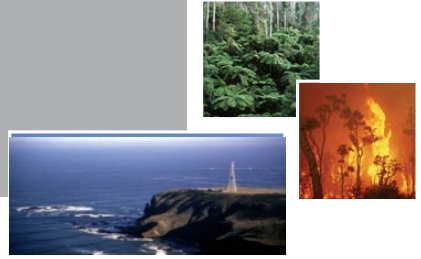


# Conclusions



- Chemical transport model outputs are very sensitive to emission factors
- Modelling suggests that both the fire and urban emissions make a contribution to the formation of secondary pollutants and aerosol chemical composition
- Model predicts that the aged plumes are ~ 2 days old
- GLObal Model of Aerosol Processes (GLOMAP) will provide more specific information about composition of growing particles, CCN



- All sources – RI = mainland influence
- All sources – mainland = fire influence

- This gives contribution of each source above background

# GLOMAP
## GLObal Model of Aerosol Processes

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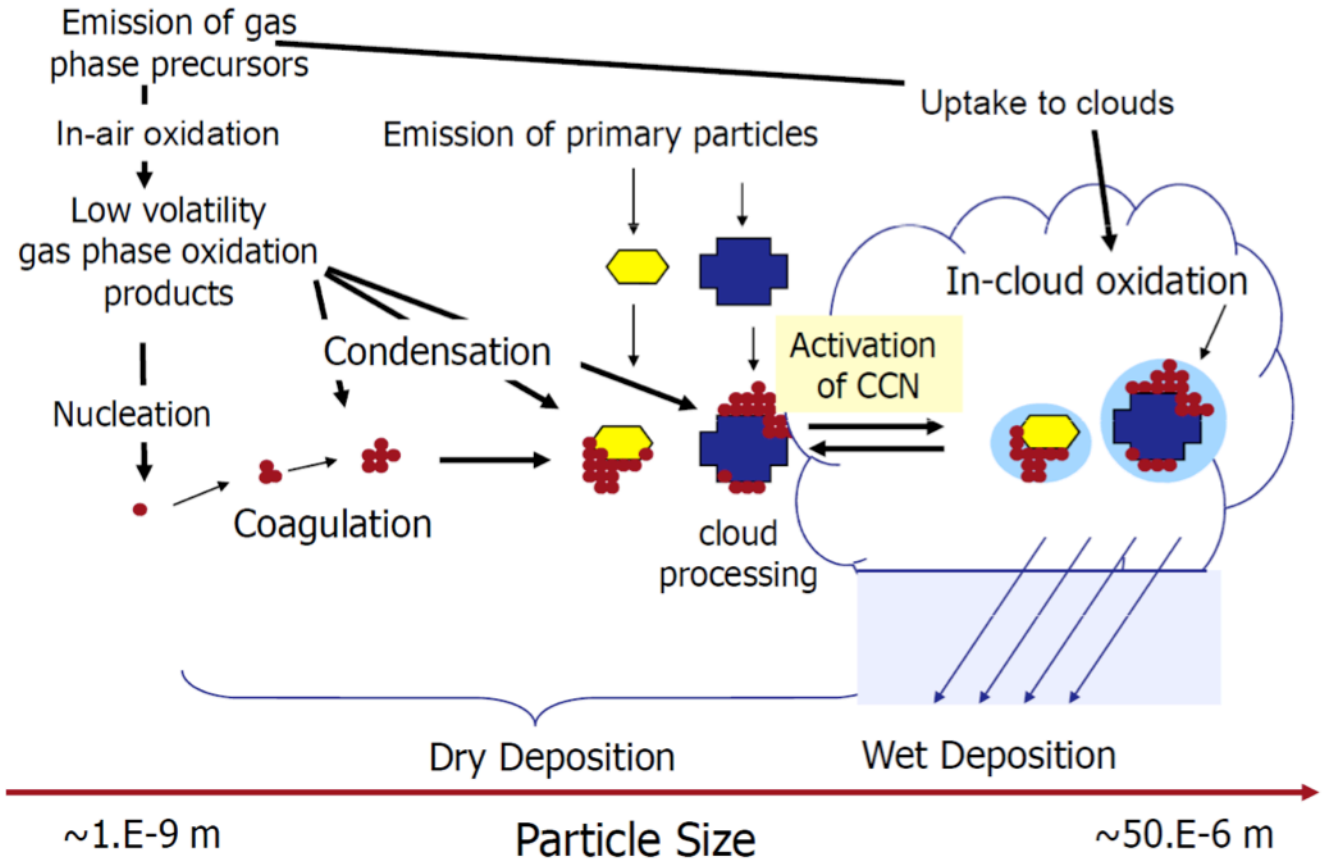


Developed in Leeds since 2003 to simulate global aerosol with size-resolved number and composition. Resolves processes that grow aerosol from nm to CCN sizes and beyond

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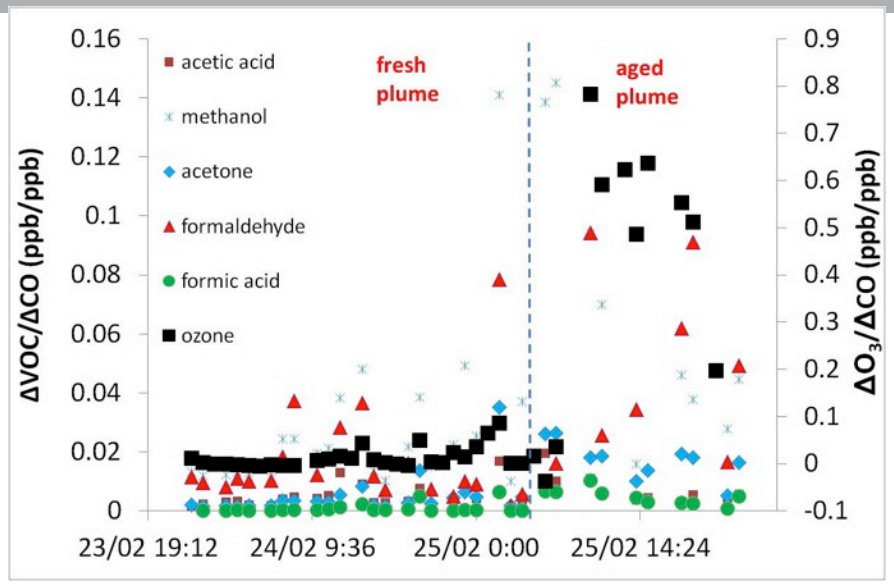
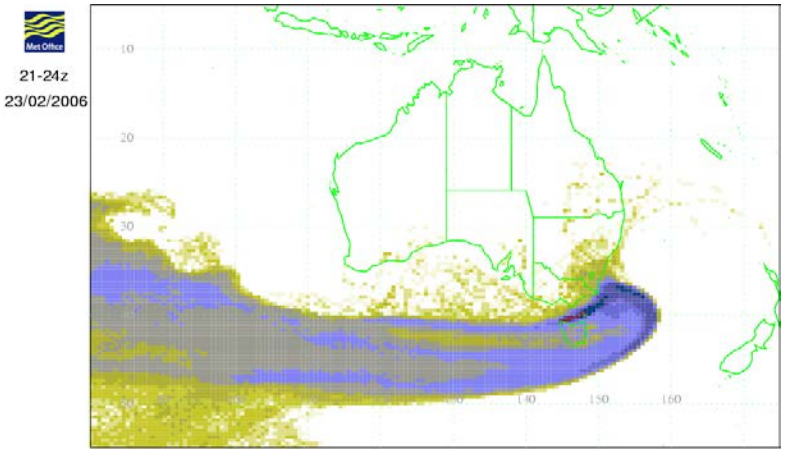
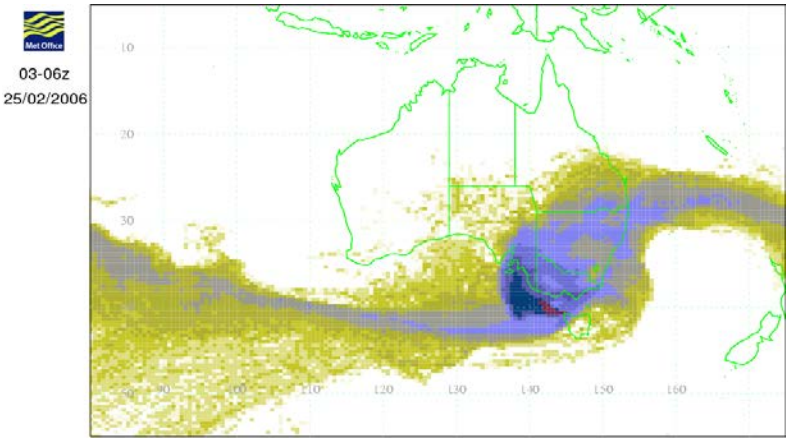
# Ozone and oxygenated VOCs enhanced in aged plume

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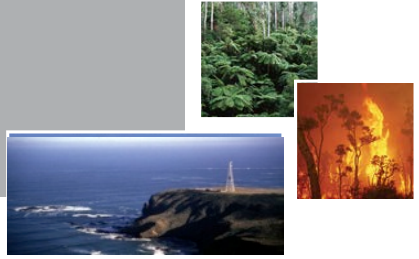
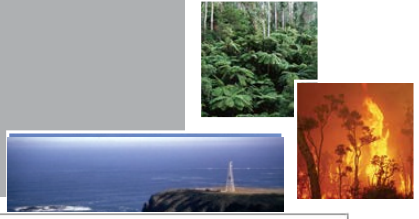
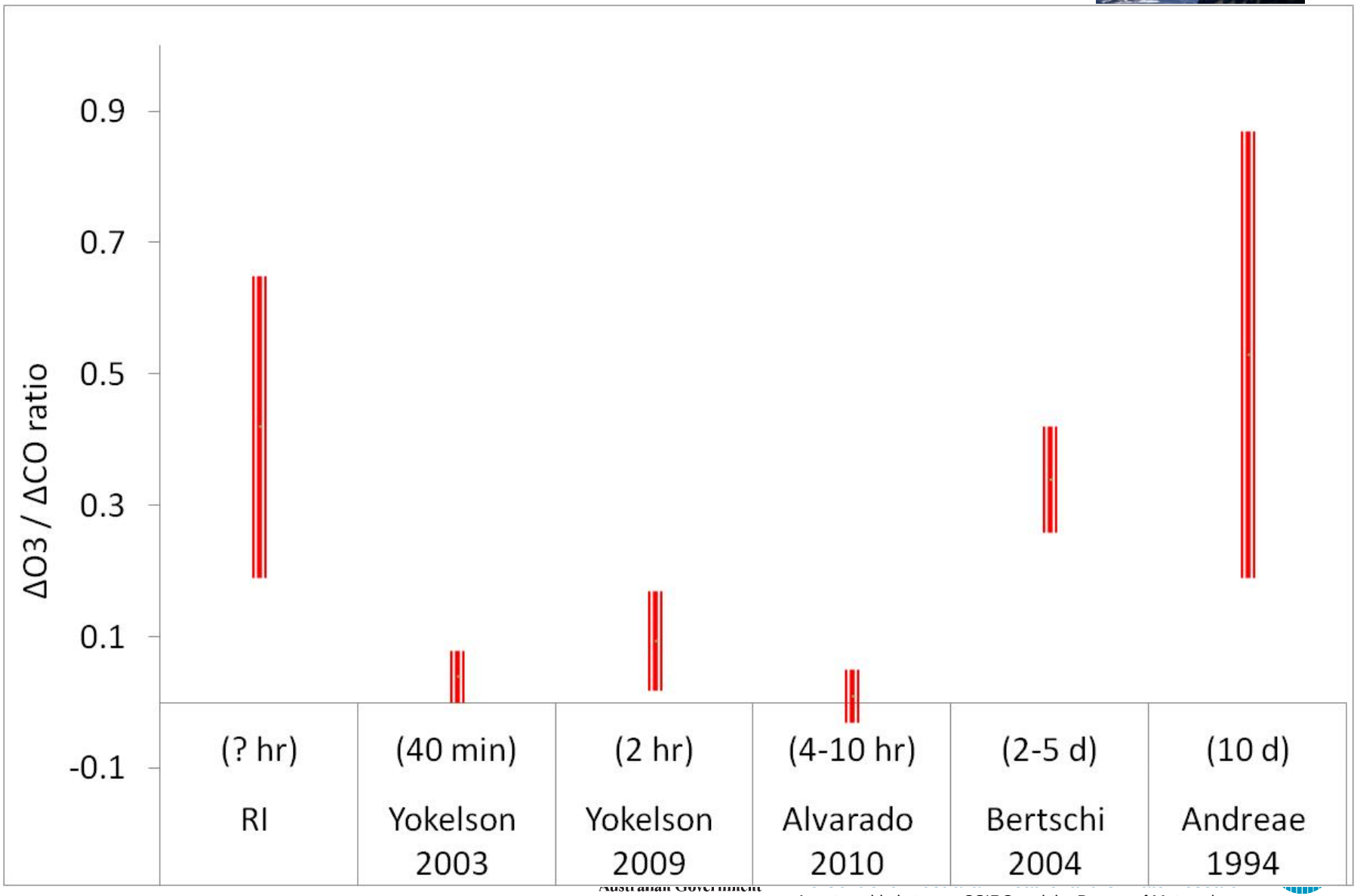


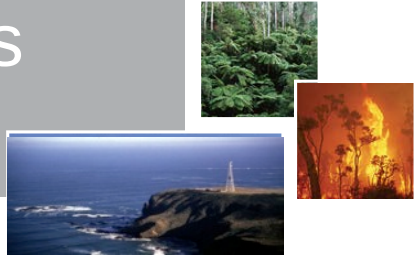
| Species | This study | Temperate south eastern Australia | Tropical Savanna, northern Australia | | | | Temperate Northern Hemisphere | |
|---|---|---|---|---|---|---|---|---|
| | g $kg^{-1}$ (calculated using Agaki 2011 CO EF of 89 g $kg^{-1}$) | Paton Walsh et al (2005, 2008) | Paton Walsh et al (2010) | Hurst (1994a, 1994b) | Meyer et al (2012) | Shirai et al (2003) | Agaki et al Temperate (2011) | Yokelson et al Semi arid shrubland (2013) |
| Hydrogen ($H_2$) | 0.64 | n/a | n/a | n/a | n/a | n/a | 2.03 (1.79) | n/a |
| Methane ($CH_4$) | 2.49 | n/a | n/a | 2.26-2.33 | 2.03 (0.13) | 2.20 (0.32) | 3.92 (2.39) | 3.69 (1.36) |
| Ethane ($C_2H_6$) | 0.30 | 0.26 (0.11) | 0.13 (0.04) | 0.11-0.60 | n/a | 0.53 (0.02) | 1.12 (0.67) | 0.48 (0.61) |
| Hydrogen cyanide (HCN) | 0.49 | 0.43 (0.22) | 0.11 (0.04) | 0.024-0.035 | n/a | n/a | 0.73 (0.19) | 0.75 (0.26) |
| Acetonitrile ($CH_3CN$) | 0.17 | n/a | n/a | 0.11 | n/a | n/a | n/a | 0.15 (0.07) |
| Acetaldehyde ($C_2H_4O$) | 0.62 | n/a | n/a | 0.55-1.0 | n/a | n/a | n/a | 0.56 (0.40) |
| Phenol ($C_6H_5OH$) | 0.24 | n/a | n/a | n/a | n/a | n/a | 0.33 (0.38) | 0.45 (1.9) |
| Acetic acid ($CH_3COOH$) | 0.52 | n/a | n/a | n/a | n/a | n/a | 1.97 (1.66) | 1.91 (0.94) |
| Methanol ($CH_3OH$) | 1.37 | 2.3 (0.8) | n/a | n/a | n/a | n/a | 1.93 (1.38) | 1.35 (0.4) |
| Benzene ($C_6H_6$) | 0.47 | n/a | n/a | 0.29 – 0.42 | n/a | 0.21 (0.02) | n/a | 0.45 (0.29) |
| Toluene ($C_7H_8$) | 0.20 | n/a | n/a | n/a | n/a | n/a | n/a | 0.17 (0.13) |
| Methyl chloride ($CH_3Cl$) | 0.2082 | n/a | n/a | n/a | n/a | 0.0605 (0.0072) | 0.059* | n/a |
| Methyl bromide ($CH_3Br$) | 0.0148 | n/a | n/a | n/a | n/a | 0.0018 (0.0003) | 0.0036* | n/a |
| Methyl iodide($CH_3I$) | 0.0019 | n/a | n/a | n/a | n/a | 0.0013 (0.0002) | 0.0008* | n/a |

# Ozone enhancement suggests plume age of several days



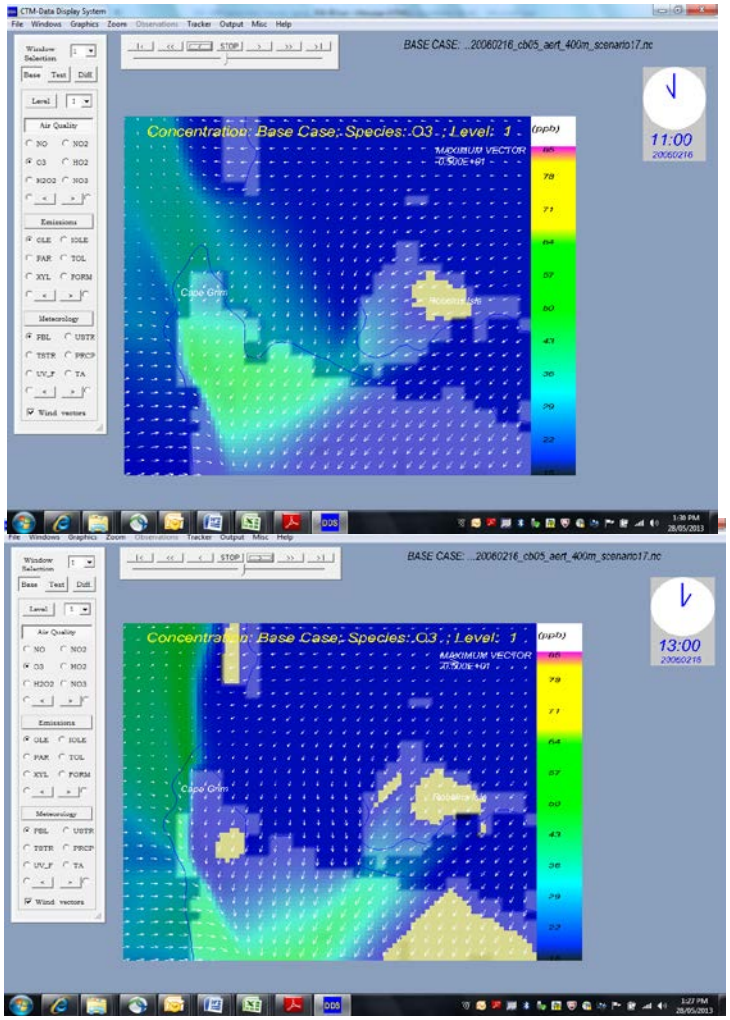


# Exploring model uncertainty- fire emissions and plume transport

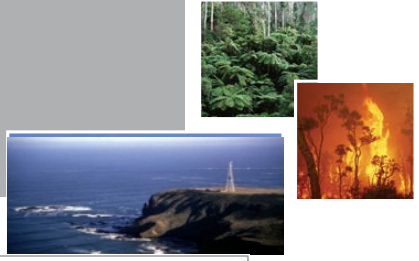


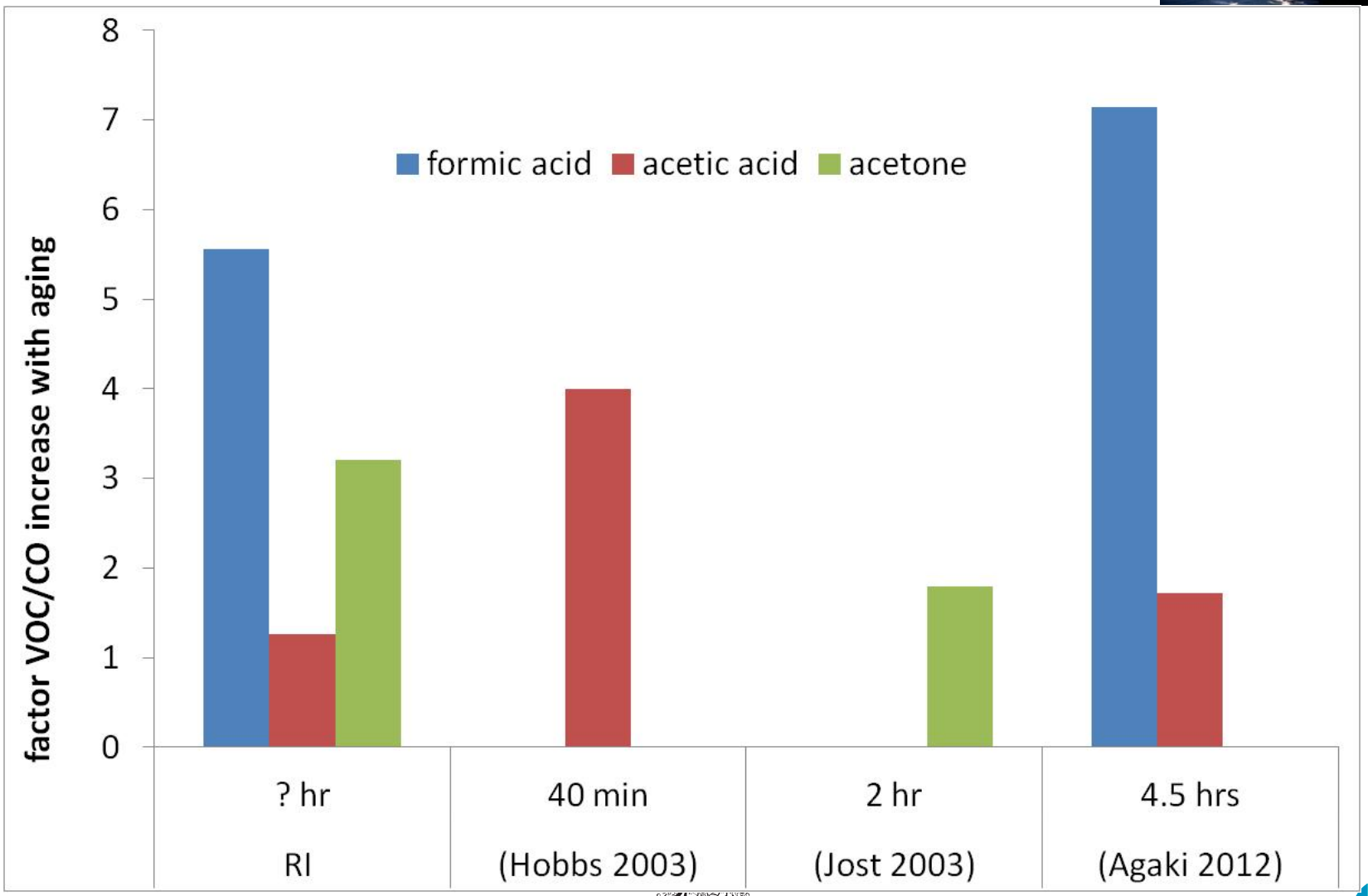
- Systematically explore sensitivity of model to varying inputs

1. Influence of different modified combustion efficiencies (MCE) and Emission Factors (EF)?
   - EF corresponding to MCE of 0.89, (lower) 0.92 (best estimate), 0.95 (upper).
2. Spatial influence?
   - Investigated modelled concs 1km north, east, south west of Cape Grim
3. Influence of different meteorology? (TAPM-CTM & CCAM)



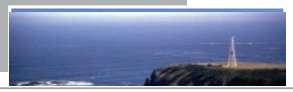
# Enhancements of OVOCs

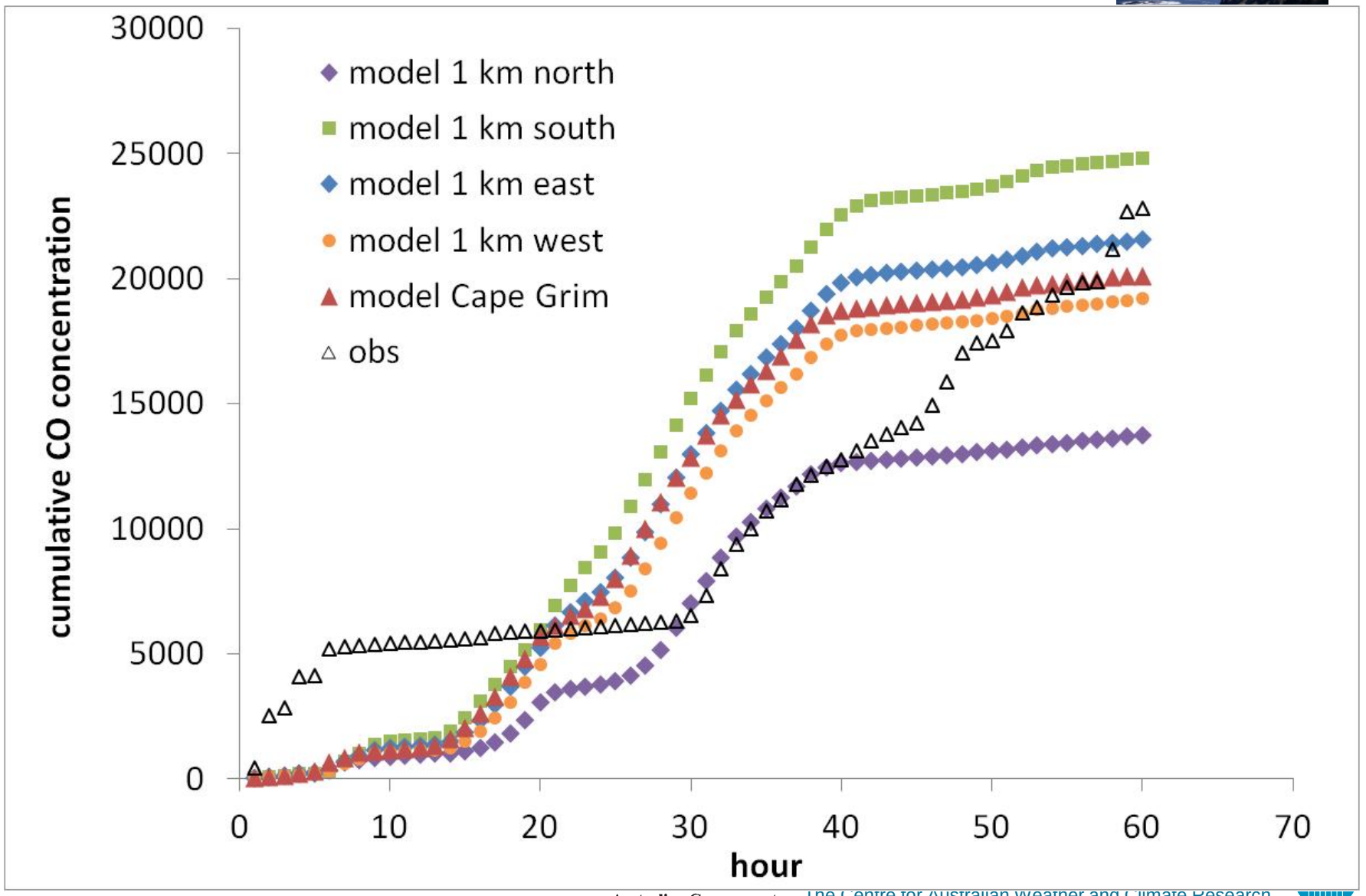




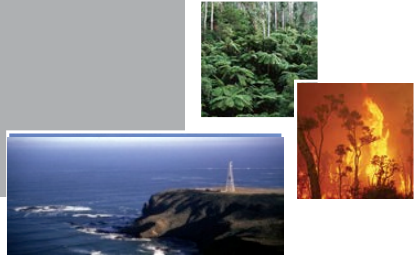
# Spatial variability – CO in direct plume (MCE 0.89)

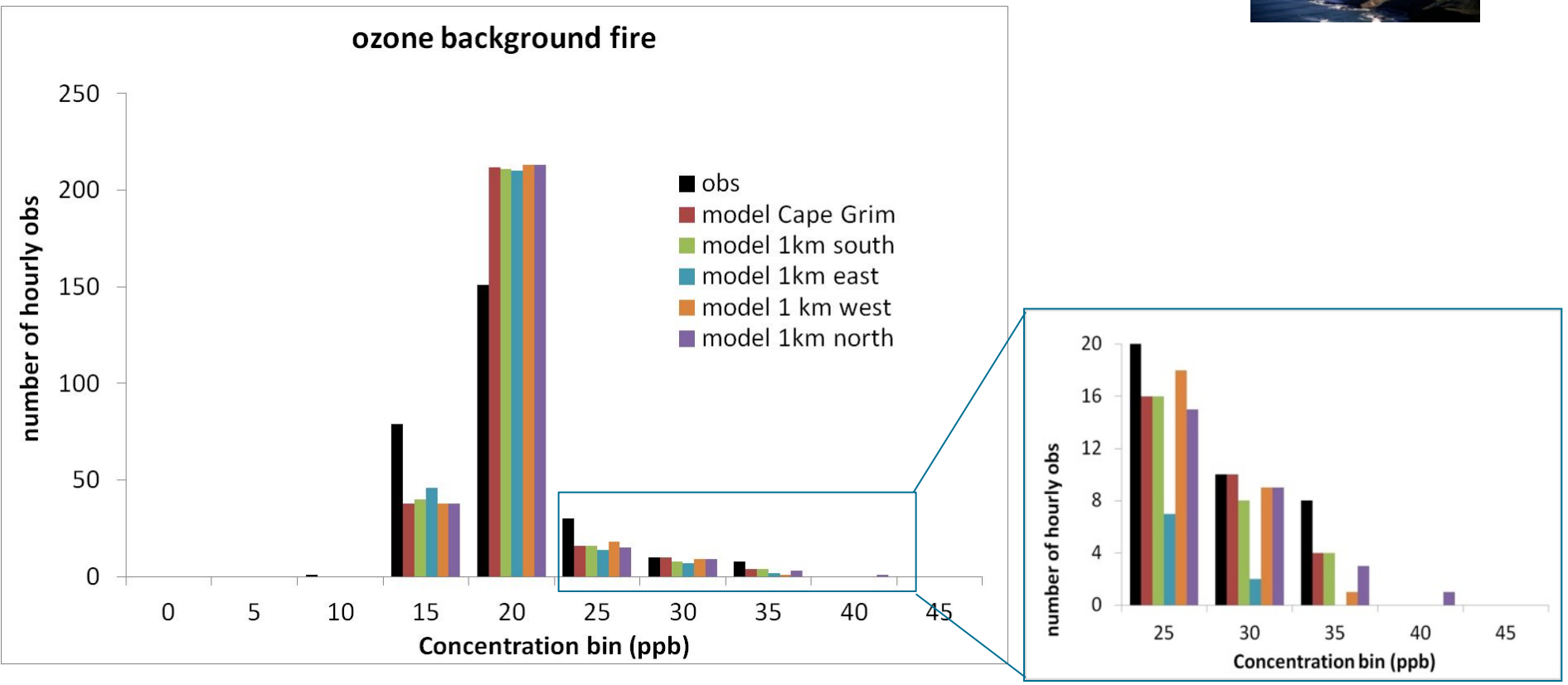






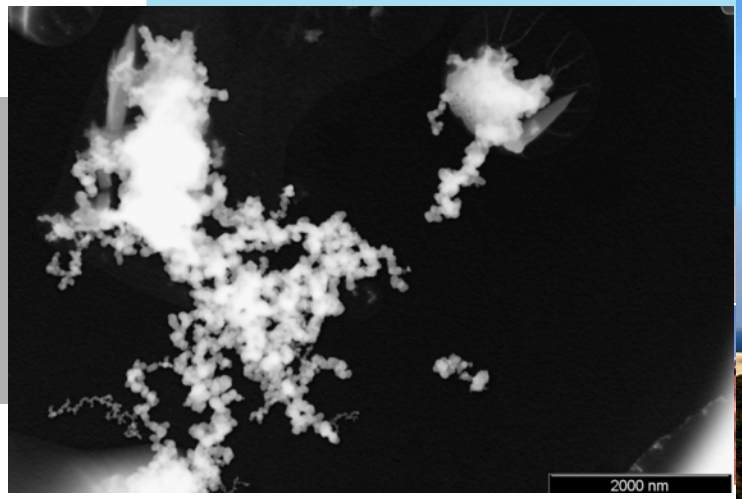
# Ozone formation in background air (MCE 0.89) – significant spatial variability






•Significant spatial variability at higher ozone concentrations (>20 ppb)

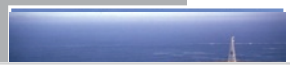

Thank you to Cape Grim Staff for their support during the Precursors to Particles campaign.

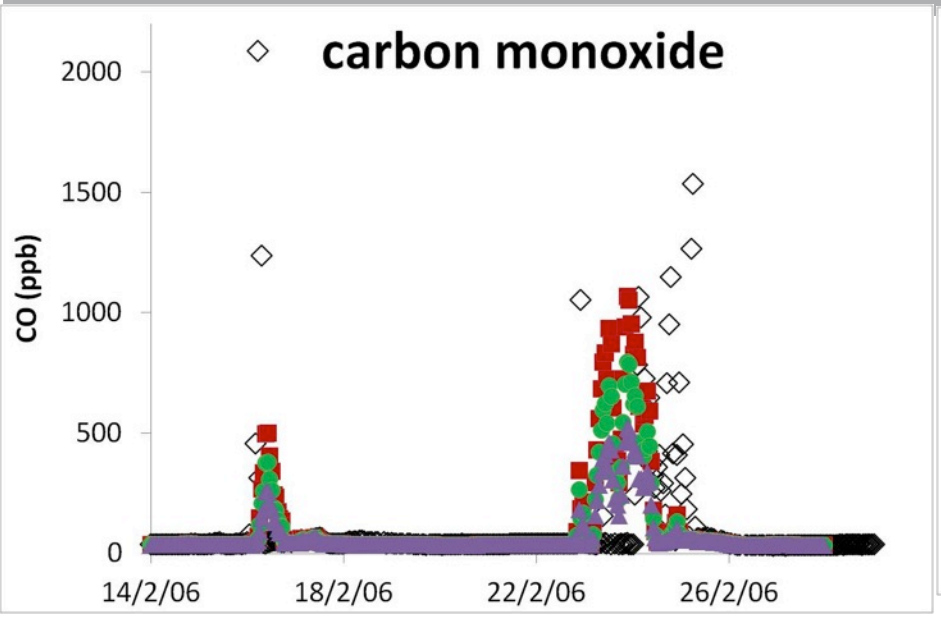


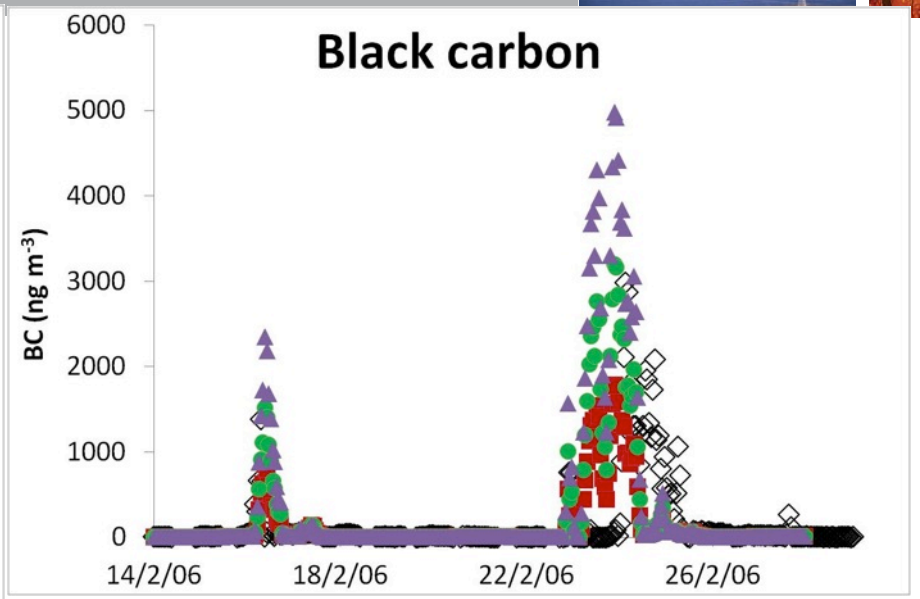

Photos: Keith Bigg

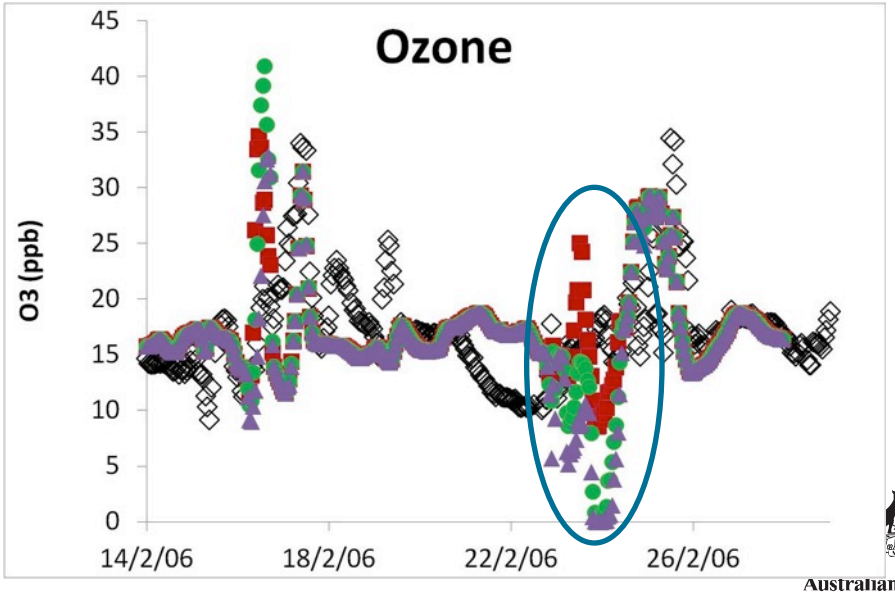
# MCE and EF have large influence on modelled concentrations







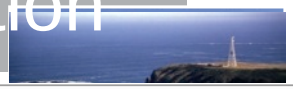

◇ obs ■ model MCE 0.89

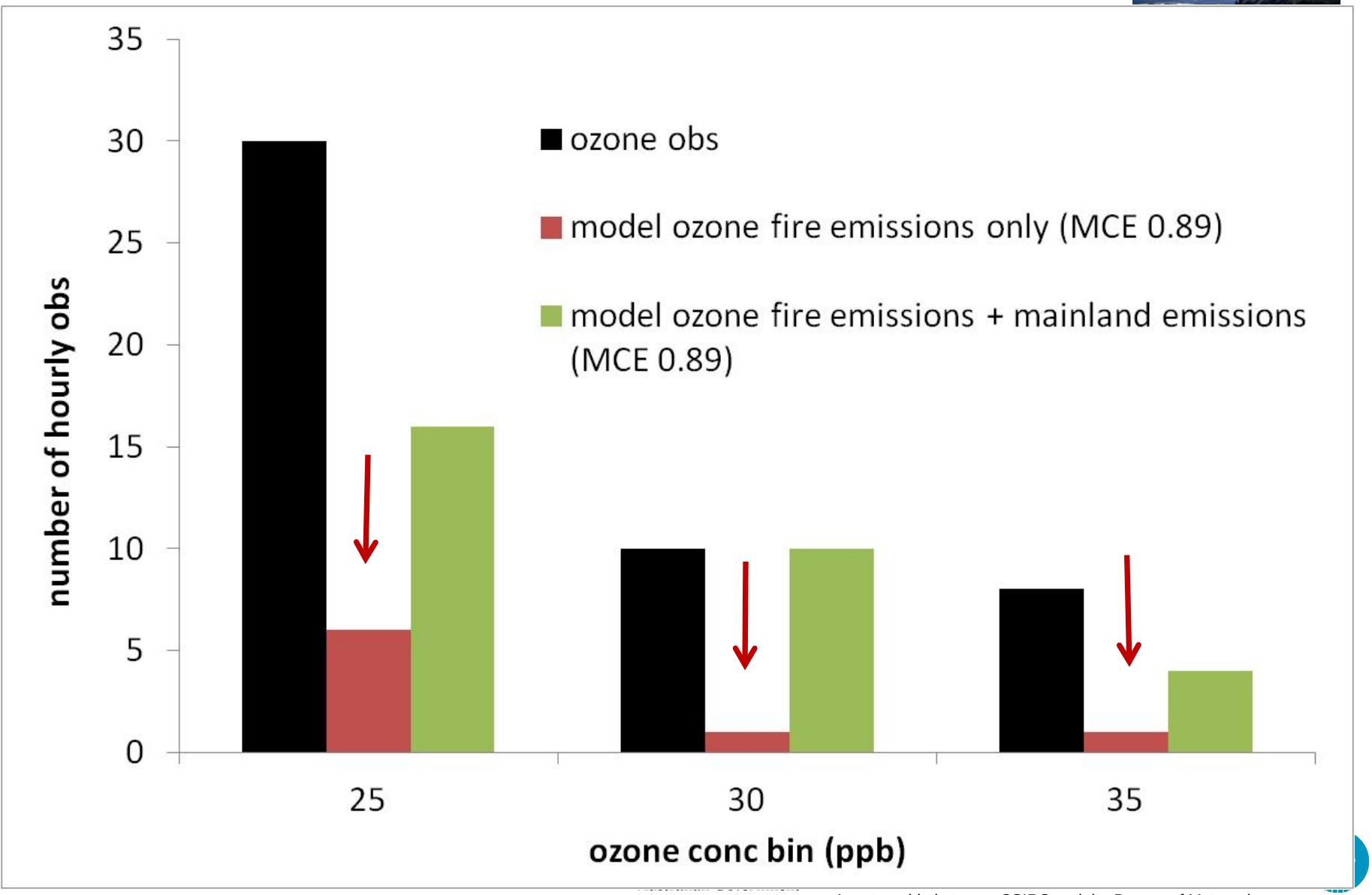
● model MCE 0.92 ▲ model MCE 0.95

- Substantial affect of MCE/EF on modelled concentrations
- EF for MCE of 0.89 appear to give best obs/model agreement

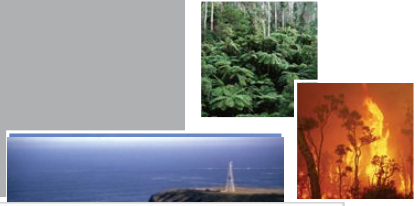
# Multiple sources are driving ozone production

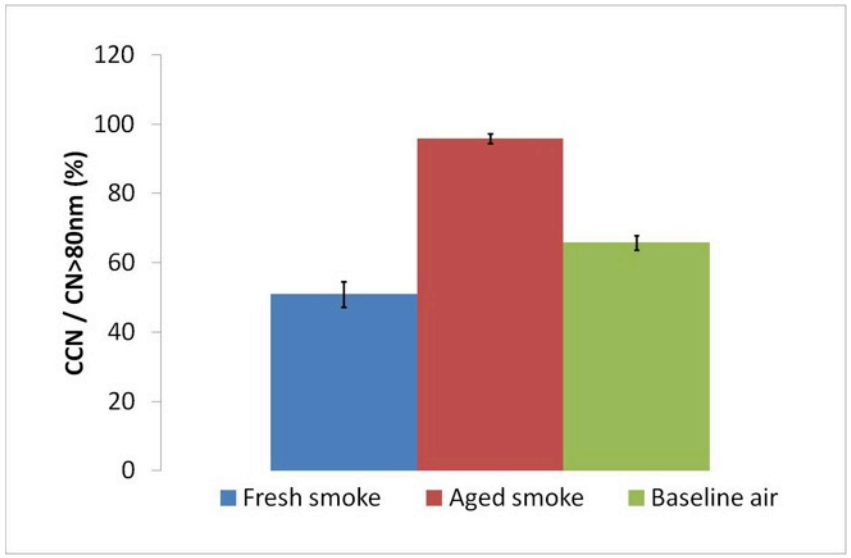


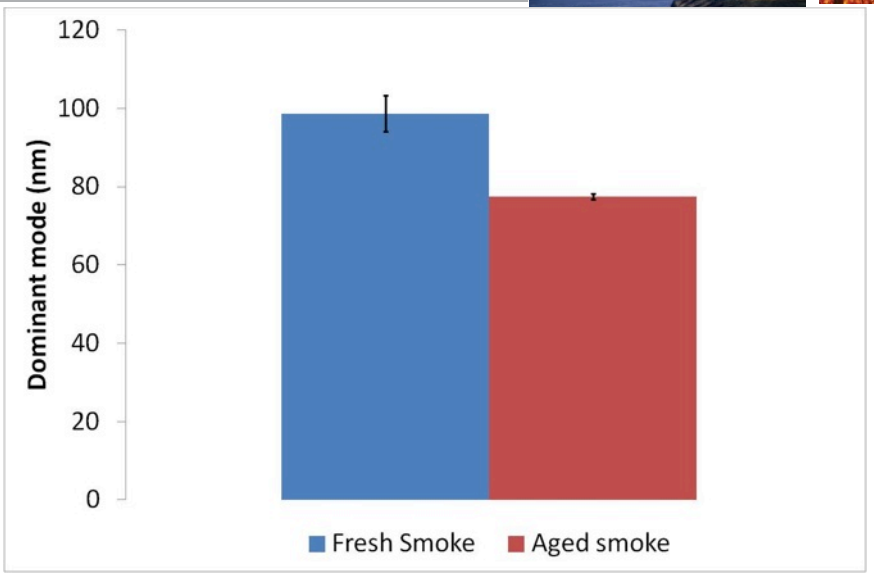


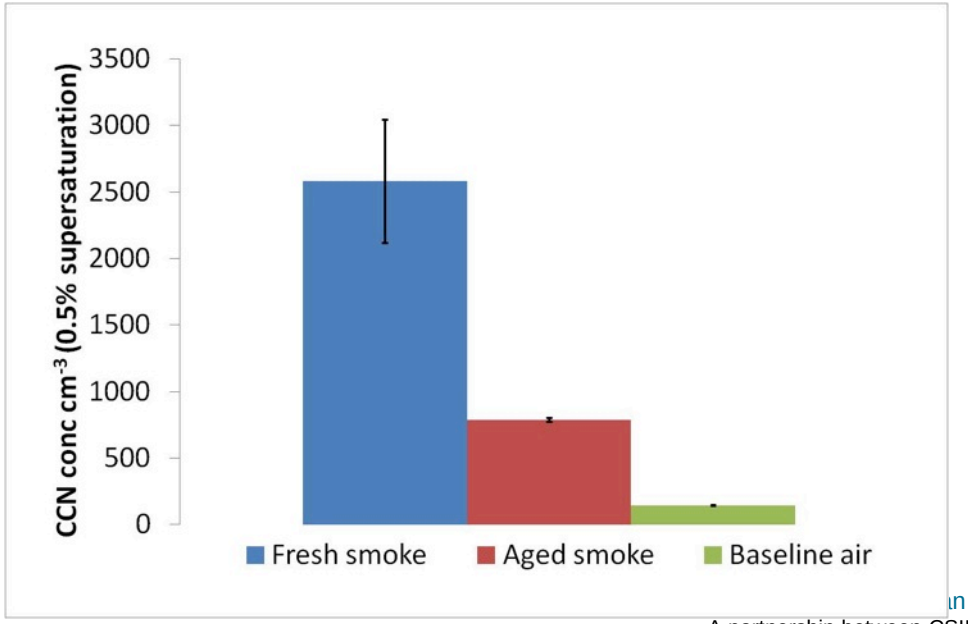


# Particle hygroscopicity changes with aging

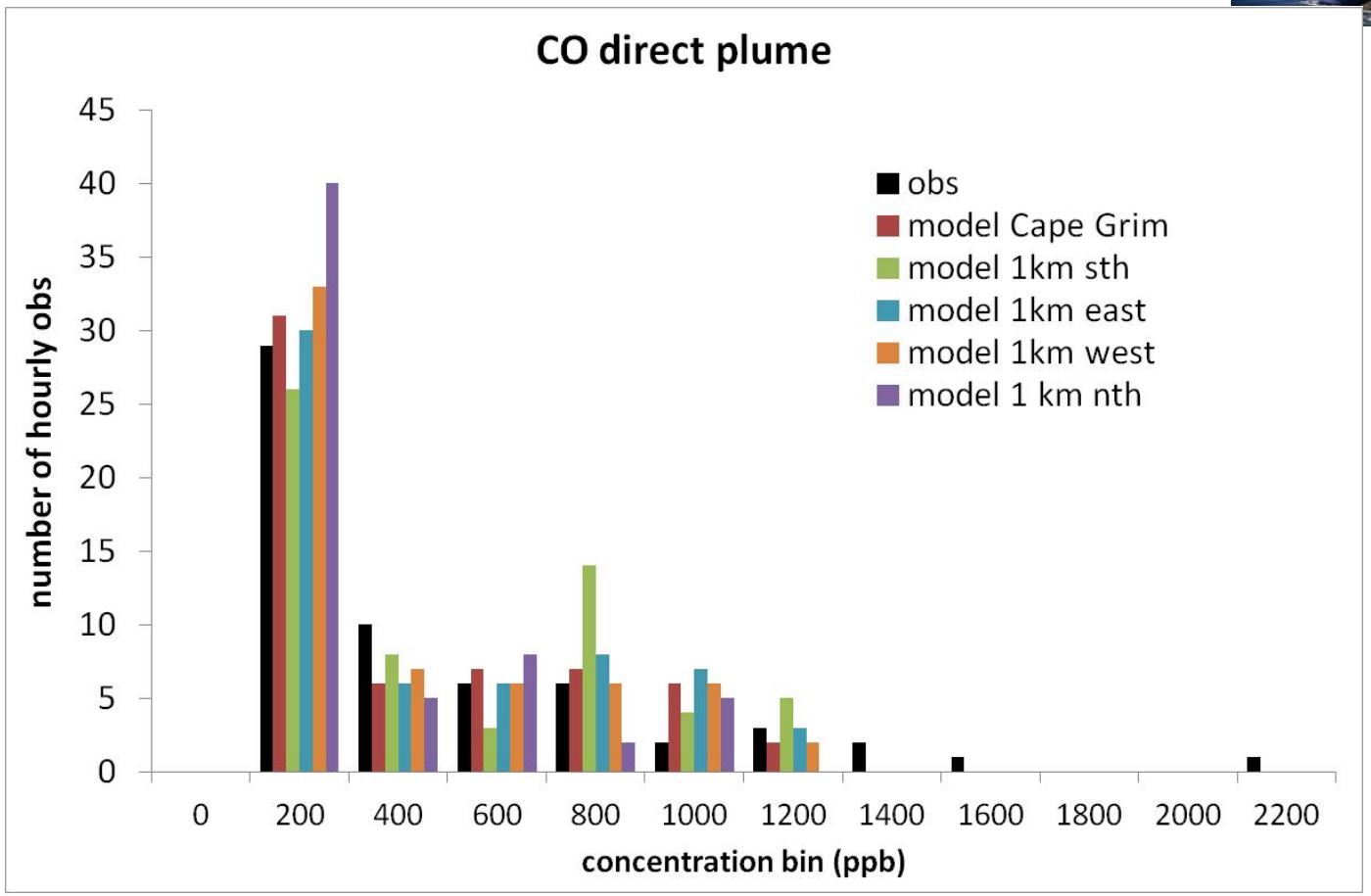




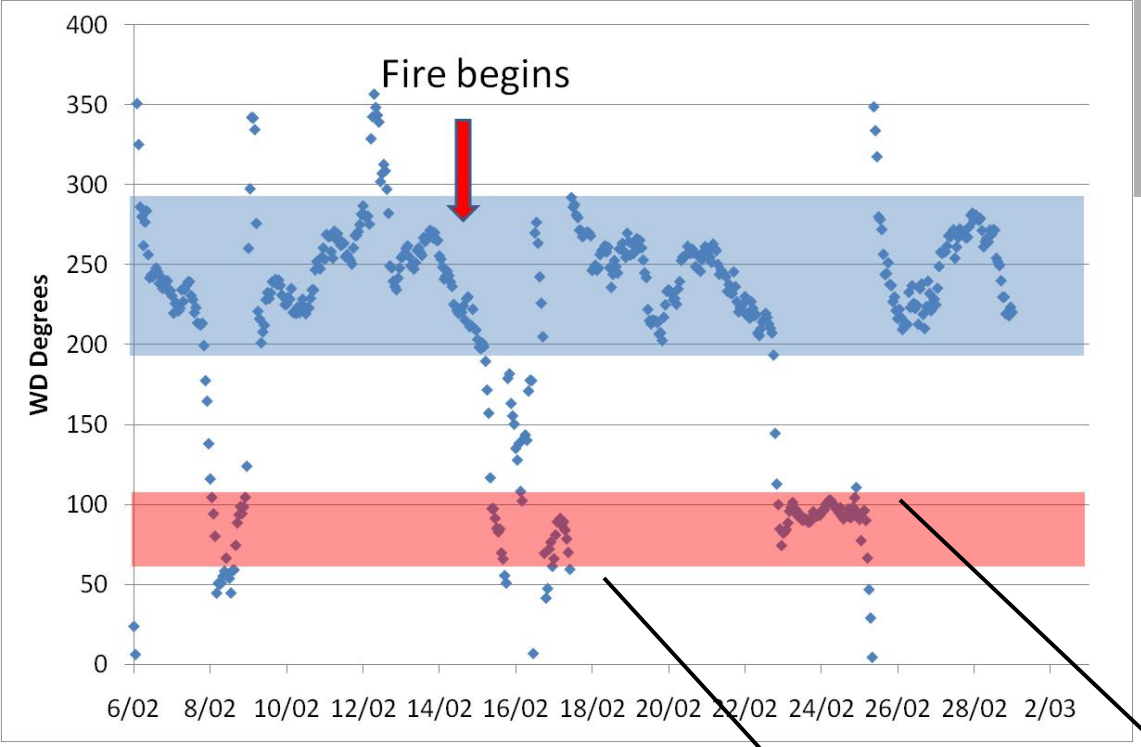



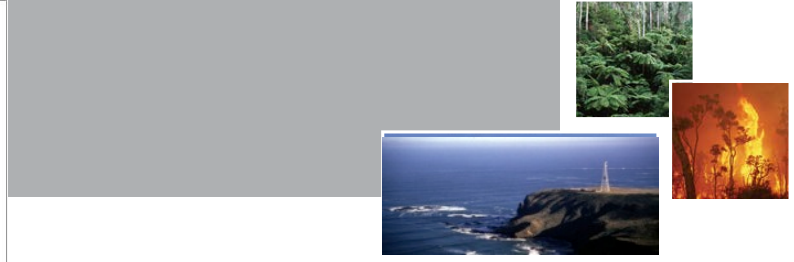



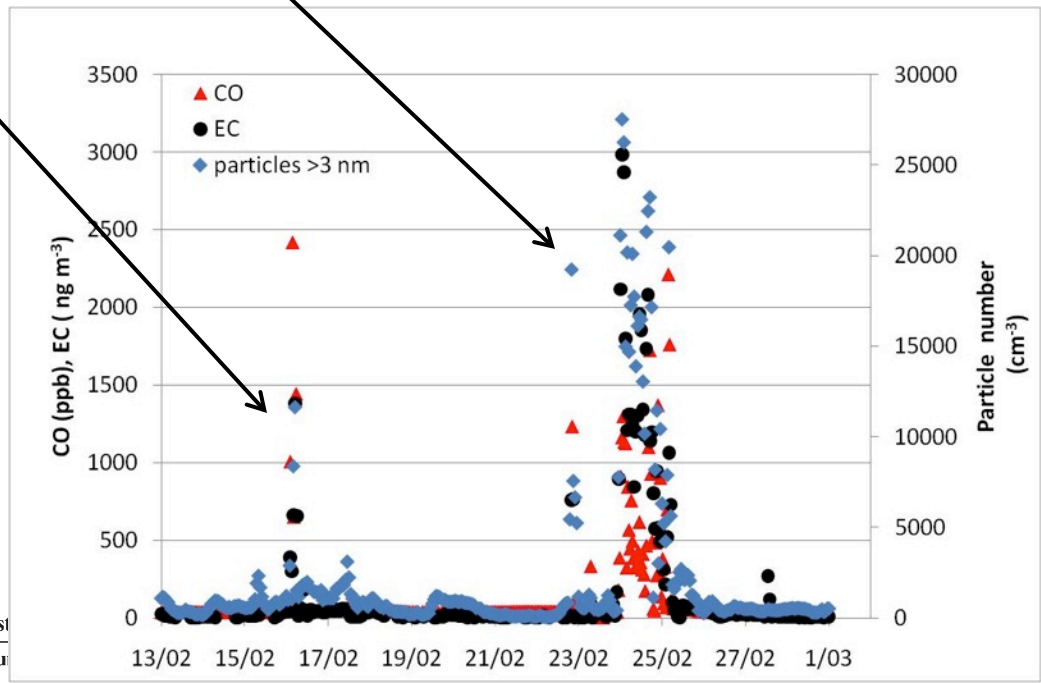
# Spatial variability – CO in direct plume (MCE 0.89)



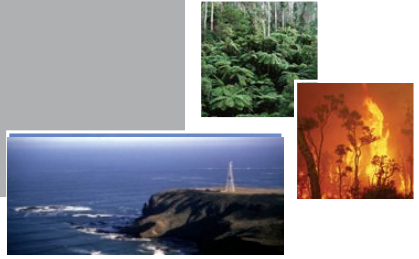

Significant spatial variability in CO concs between different modelled locations

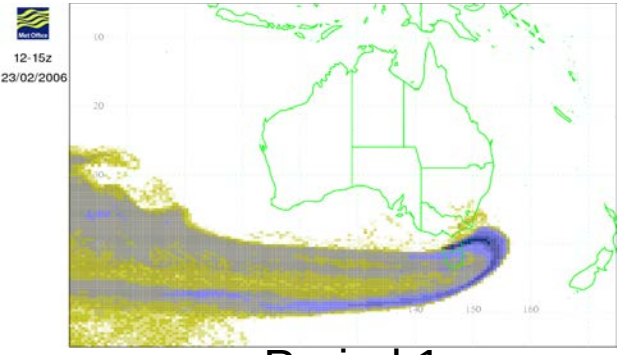

Fire begins
WD Degrees
400
350
300
250
200
150
100
50
0
6/02
8/02
10/02
12/02
14/02
16/02
18/02
20/02
22/02
24/02
26/02
28/02
2/03



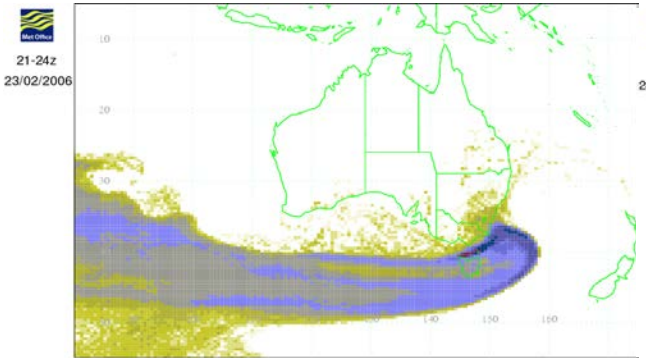

CO
EC
particles >3 nm
CO (ppb), EC ( ng m-3)
Particle number (cm-3)
3500
3000
2500
2000
1500
1000
500
0
30000
25000
20000
15000
10000
5000
0
13/02
15/02
17/02
19/02
21/02
23/02
25/02
27/02
1/03

# Modified Combustion Efficiencies

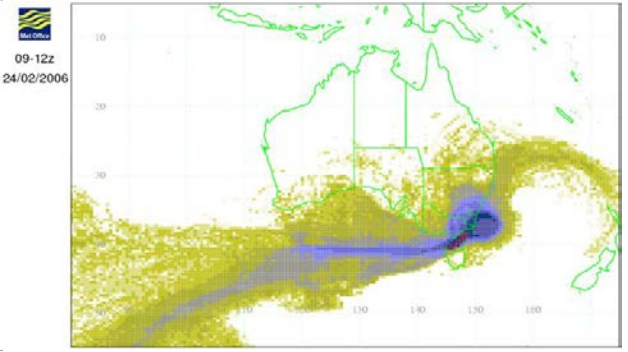





Period 1
No mainland influence

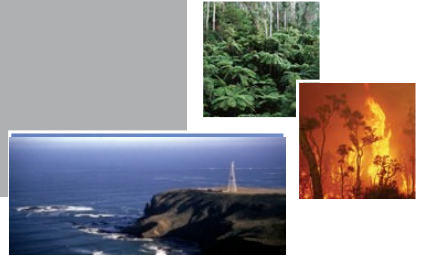



Period 2
Minor mainland influence

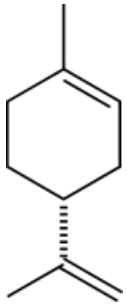



Period 3
Substantial mainland influence

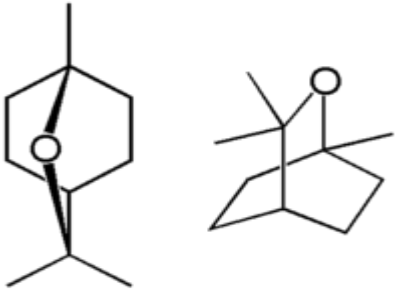
Air Map Origin Source: UK Met Office (www.metoffice.com)

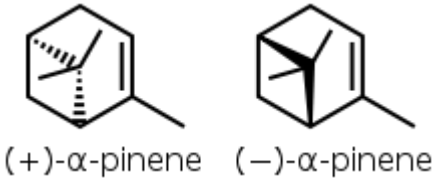


limonene

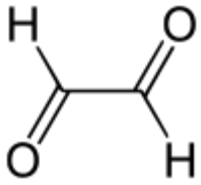


Eucalyptol

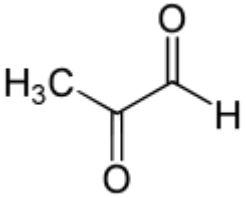




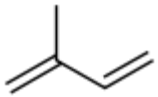

glyoxal



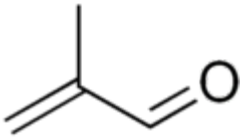

Methyl glyoxal



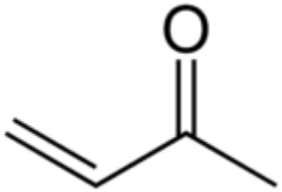

isoprene



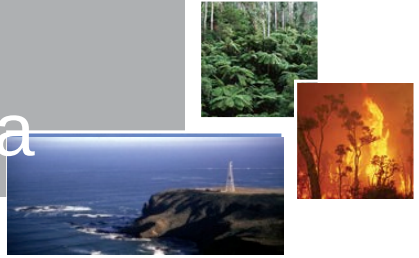
methacrolein

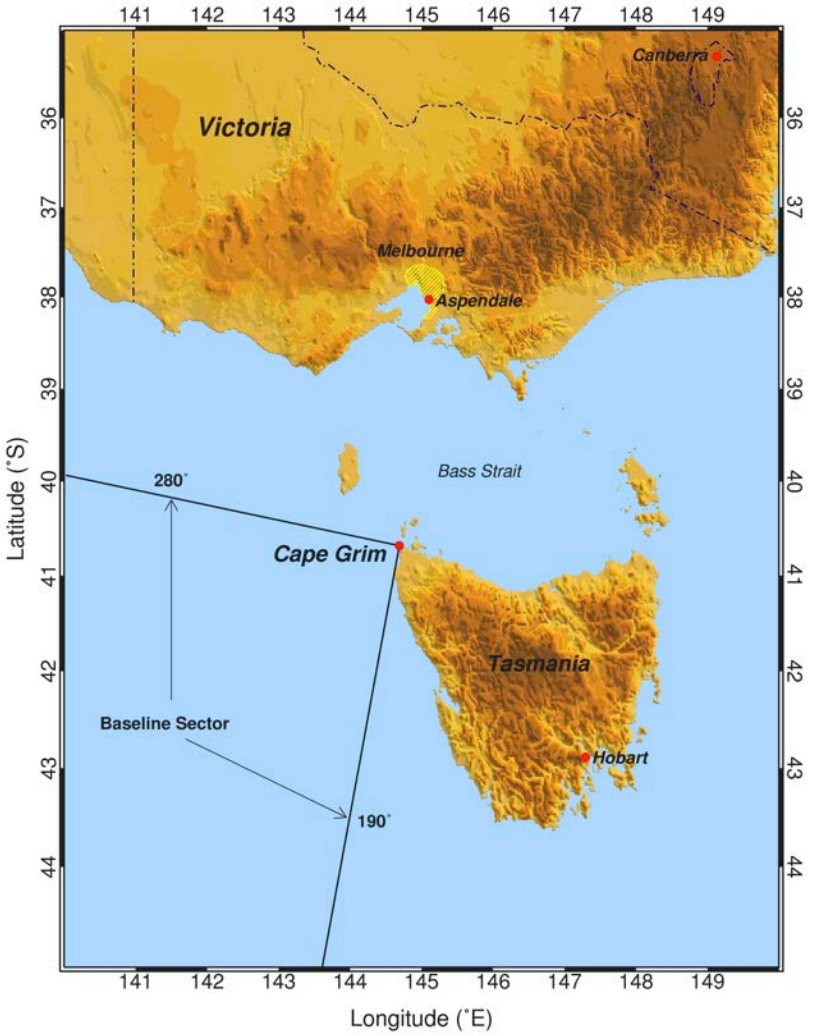



MVK



# Cape Grim Baseline Station, NW Tasmania



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CSIRO