



Rapid transport of East Asian pollution to the deep tropics

Matthew J. Ashfold

School of Environmental and Geographical Sciences

University of Nottingham Malaysia Campus

matthew.ashfold@nottingham.edu.my

A. Abu Samah, S. M. Phang (UM, Malaysia)

M. T. Latif, M. S. M. Nadzir (UKM, Malaysia)

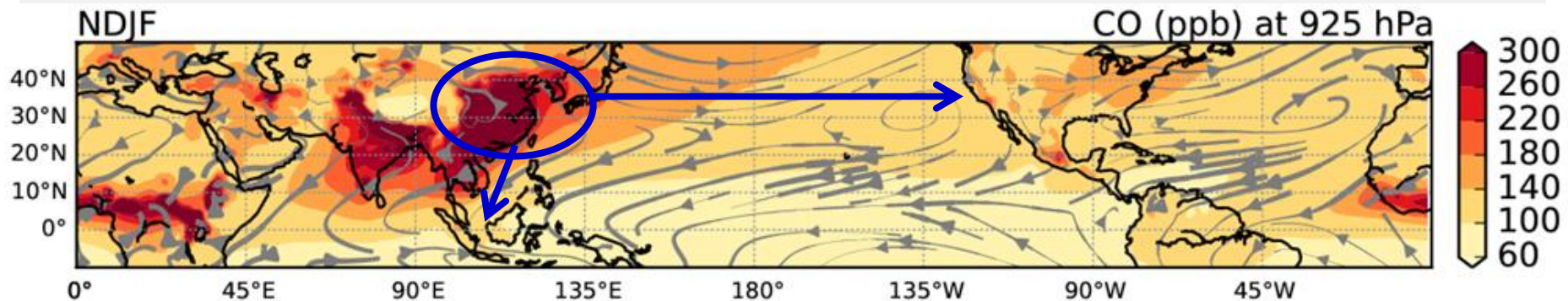
N. Harris, I. Mead (Cranfield, UK)

D. Oram, W. Sturges (UEA, UK)

A. Robinson, J. Pyle (Cambridge, UK)

Motivation

Climatology of CO in the MACC Reanalysis (MACCRA)



- East Asia – growing, large source of pollution
- Transport of pollution across the Pacific well documented (e.g. Cooper et al., Nature, 2010; Lin et al., Nature Geosci., 2014)
- But what about transport of this pollution to the tropics?
 - Mean winds and especially ‘cold surges’ provide a mechanism

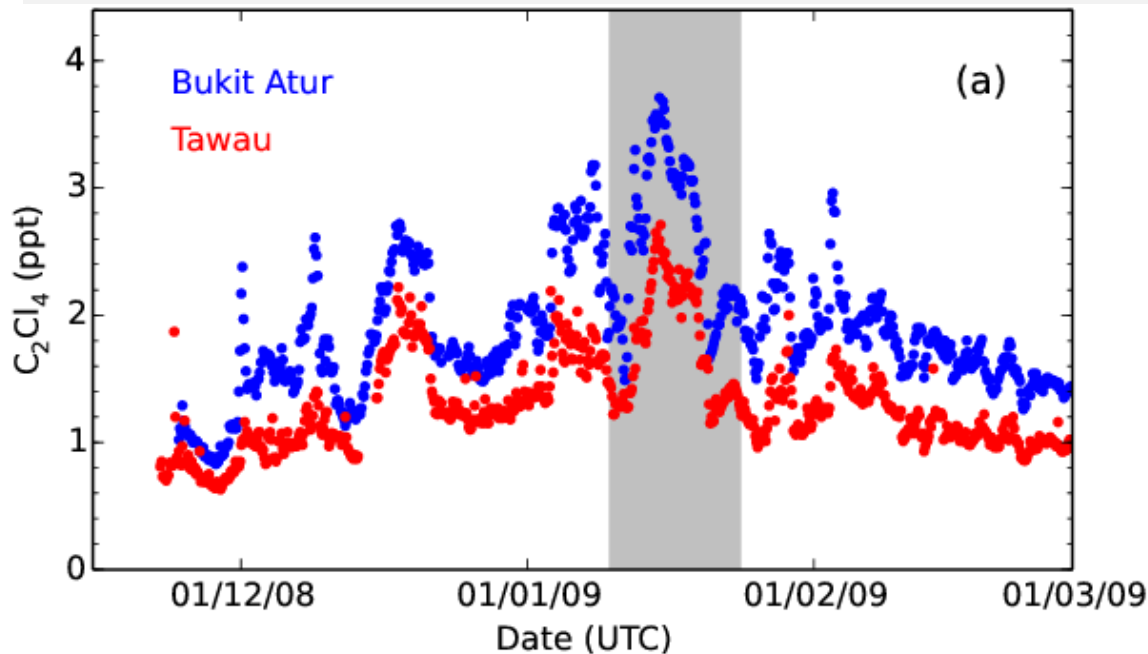


Outline

- Study of Ashfold *et al.*, Atmos. Chem. Phys., 2015
 - Observations from Malaysian Borneo
 - Modelling suggests influence of East Asian pollution linked to ‘cold surges’ in Northern Hemisphere winter
 - And possibility of subsequent tropical pollutant uplift
- Further work
 - More detailed analysis of large air quality (O_3) impacts
 - Large number of surface and aircraft observations show importance of mechanism for stratospheric ozone-depleting VSL-chlorine compounds

Case study of Ashfold *et al.* (2015)

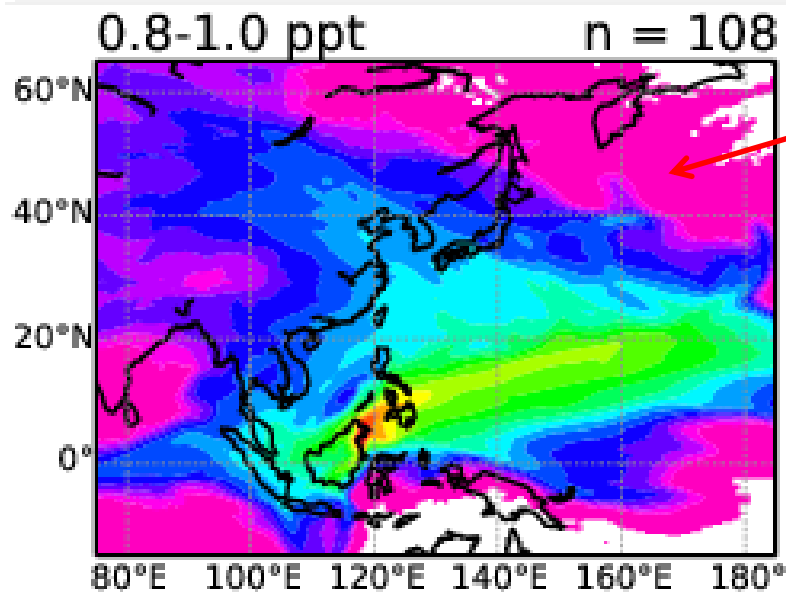
- Observations of C_2Cl_4 in **Malaysian Borneo (~4°N)**
Instrument of Gostlow *et al.* (2010)



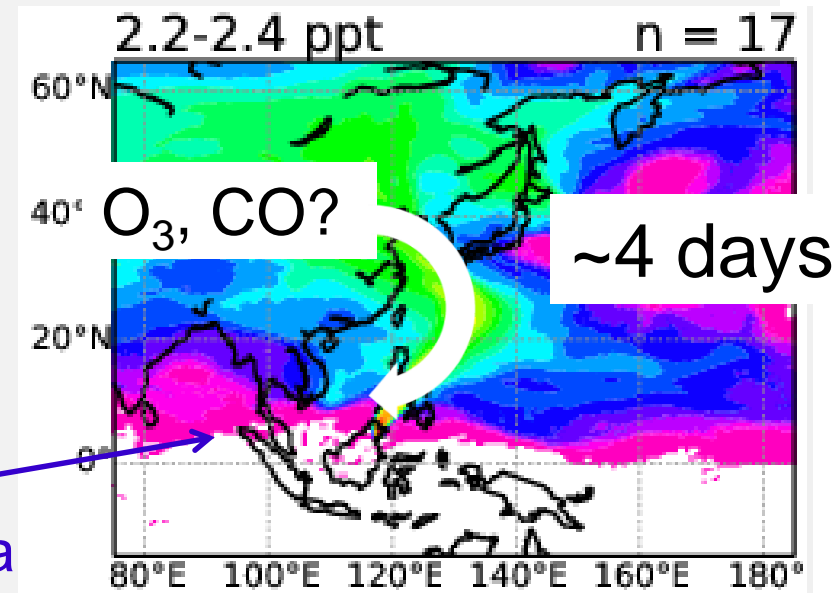
- Winter 2008/09
- One **rainforest** site; one **coastal** site
- Strong, coherent intra-seasonal variability

Case study of Ashfold *et al.* (2015)

- **NAME** model suggests influence of East Asian pollution



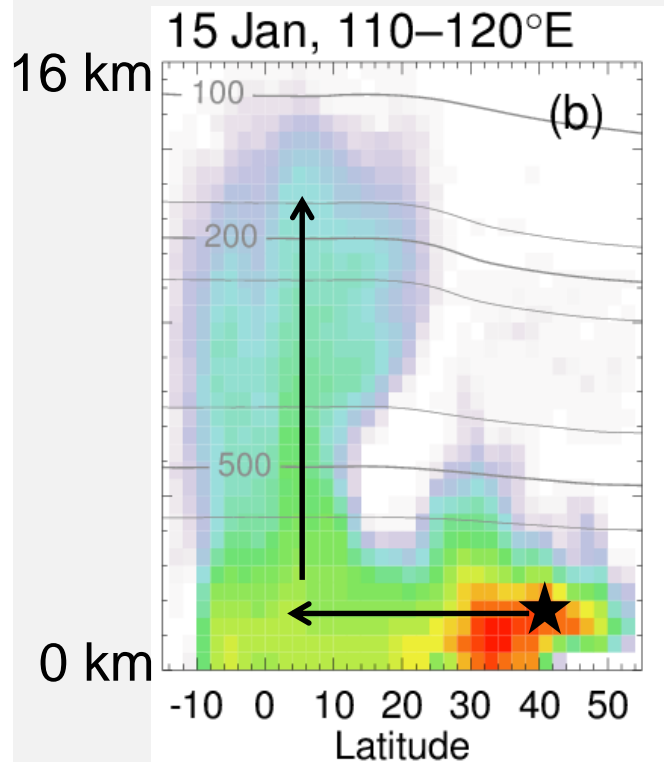
Low C_2Cl_4 , winds from Pacific



High C_2Cl_4 , 'cold surges' from East Asia

Case study of Ashfold *et al.* (2015)

- **NAME** shows possibility of tropical pollutant uplift



- Initialise forward trajectories in mid-latitudes
- Transport from East Asia to the tropics (~4 days)
- And uplift towards the stratosphere (total <10 days)



Some open questions ...

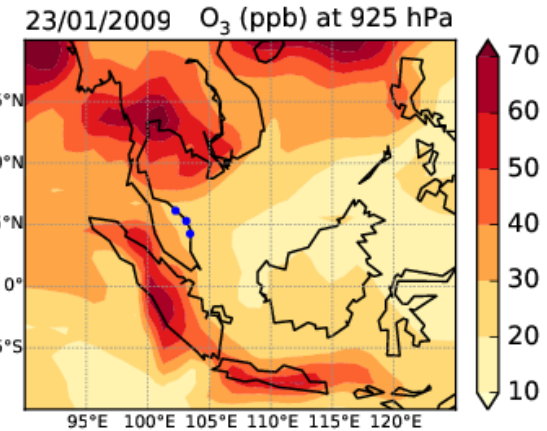
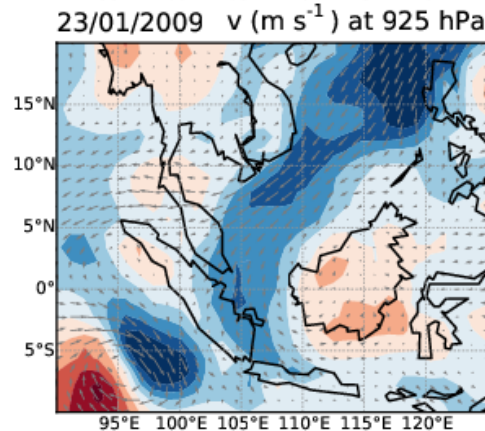
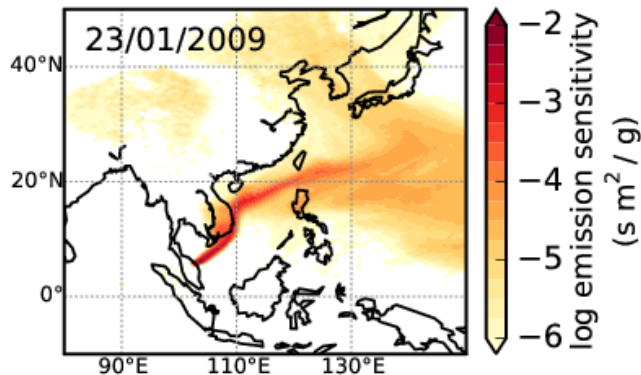
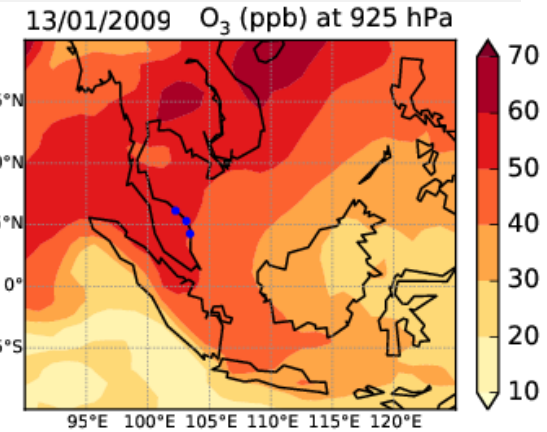
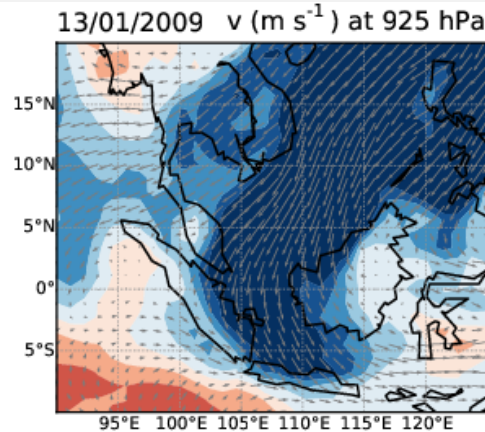
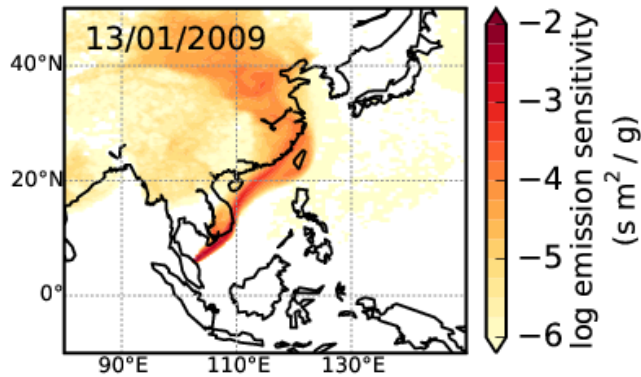
1. What is the spatial scale of this process, and does this type of transport vary with year?
2. What is the impact on composition beyond C_2Cl_4 (e.g. on air quality)?
3. How much pollution reaches the upper troposphere and the stratosphere?

Spatial scale: day-to-day variations

NAME

MACCRA v

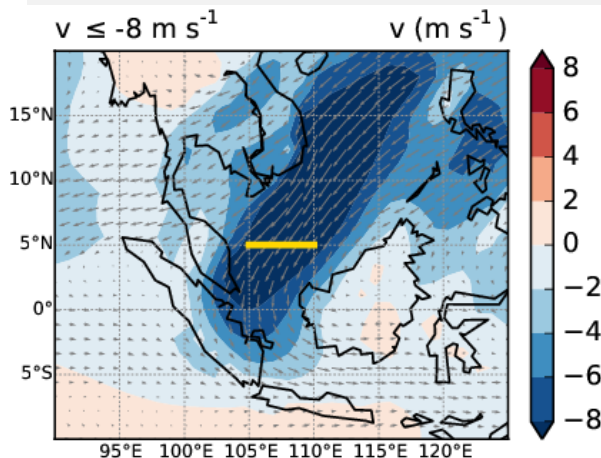
MACCRA O₃



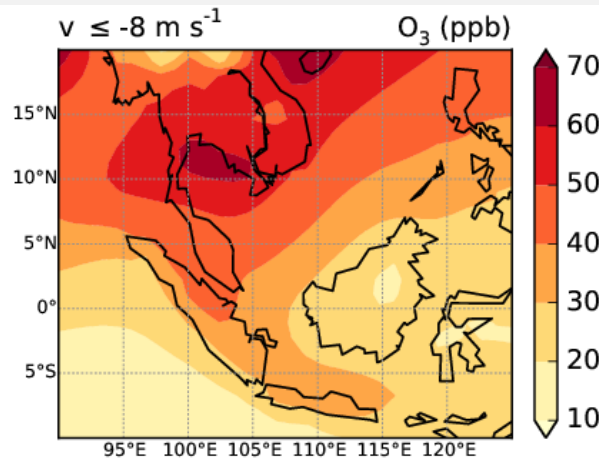
'Typical cold surge' impacts on air quality

- MACC Reanalysis (**MACCRA**) covering 2003-2012
- Following Chang et al. (2005) define cold surge index (V_5)
- $V_5 < -8 \text{ m s}^{-1}$ on $\sim 25\%$ of time-steps during NDJF

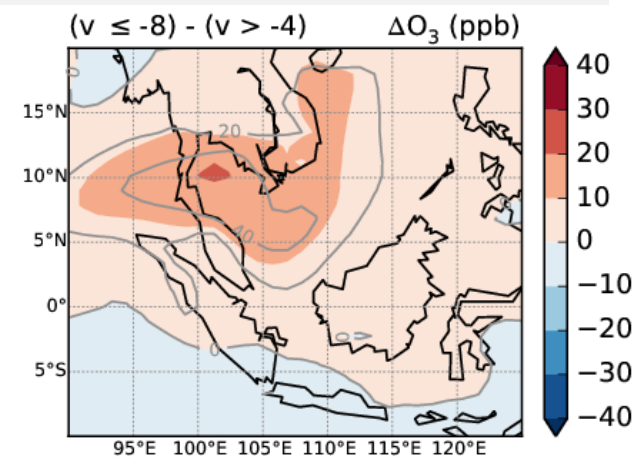
MACCRA v



MACCRA O_3

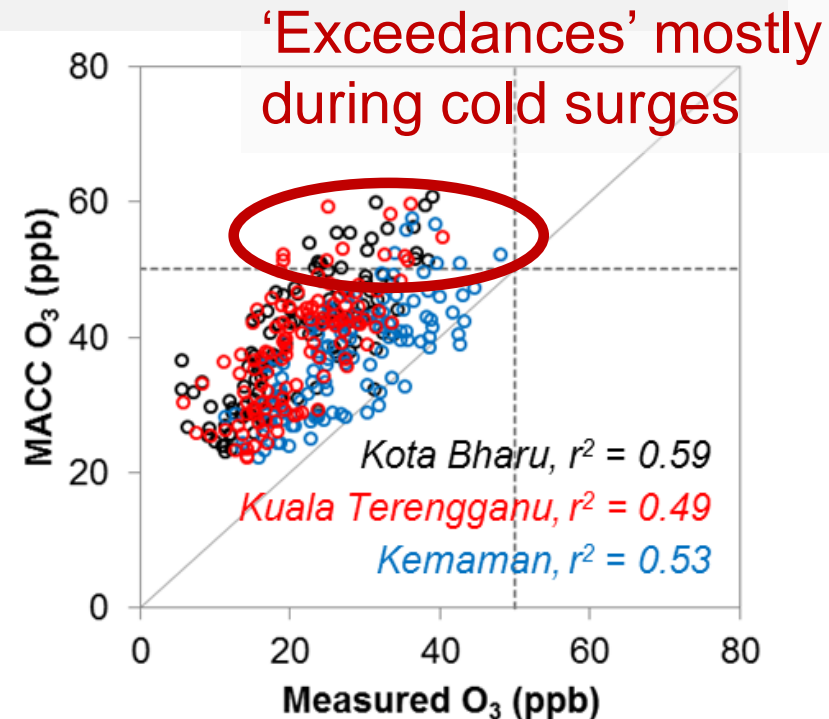
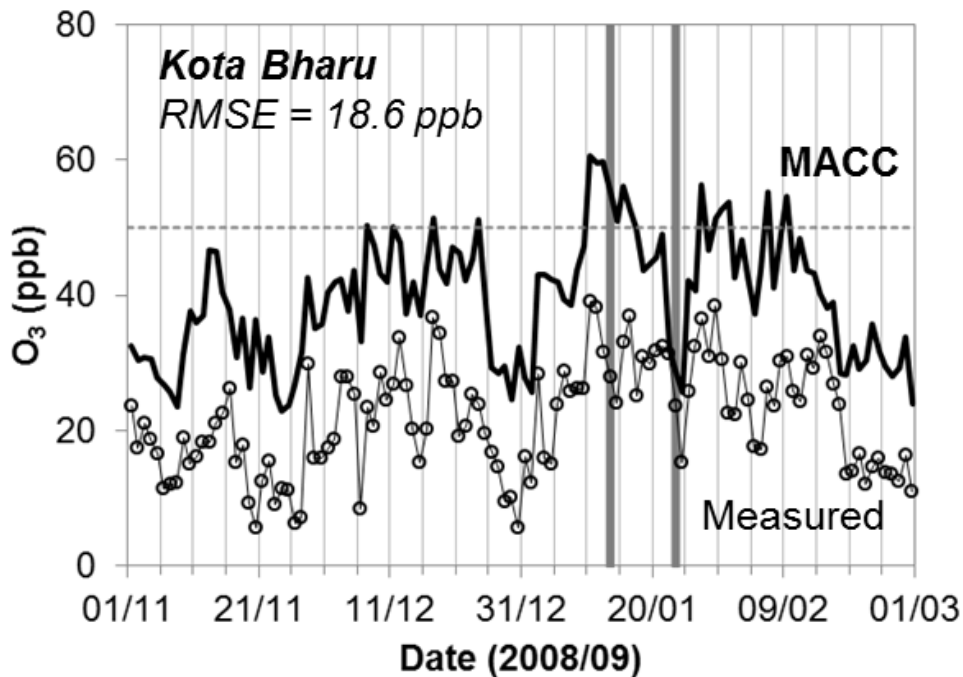


MACCRA ΔO_3

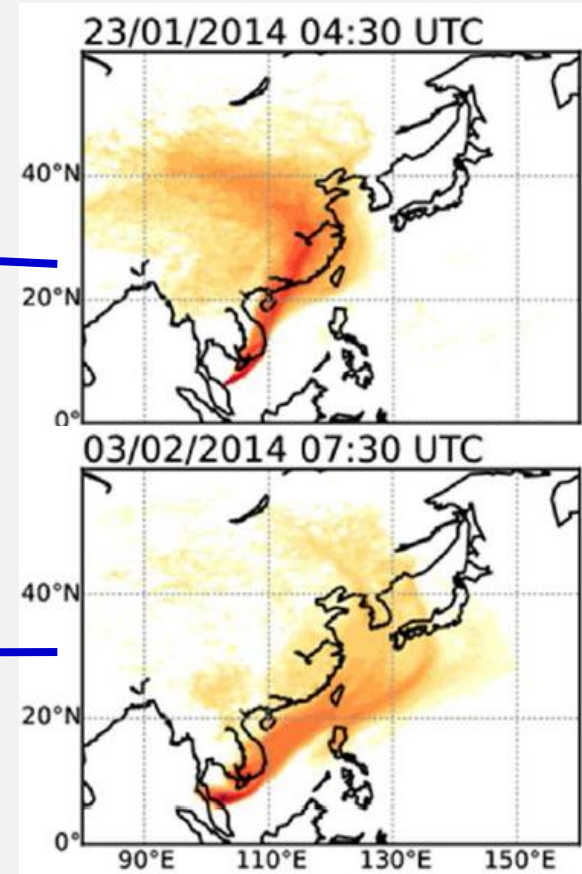
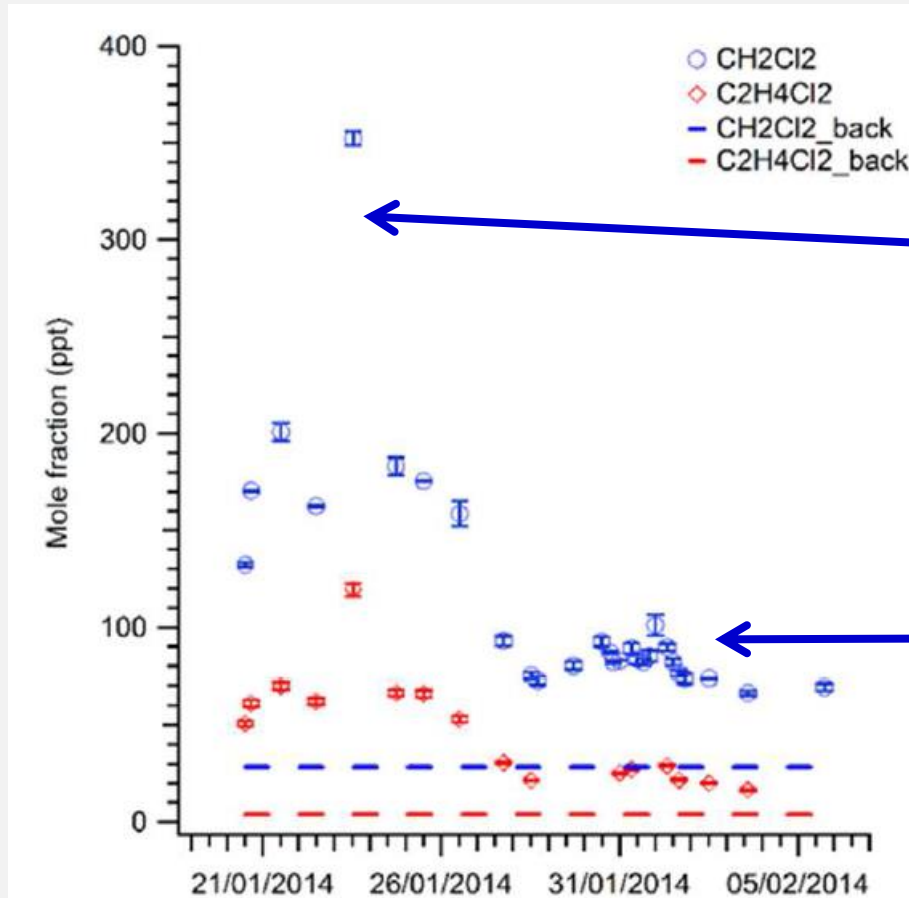


Compare MACCRA with surface observations

- Winter 08/09: similar variation but significant offset

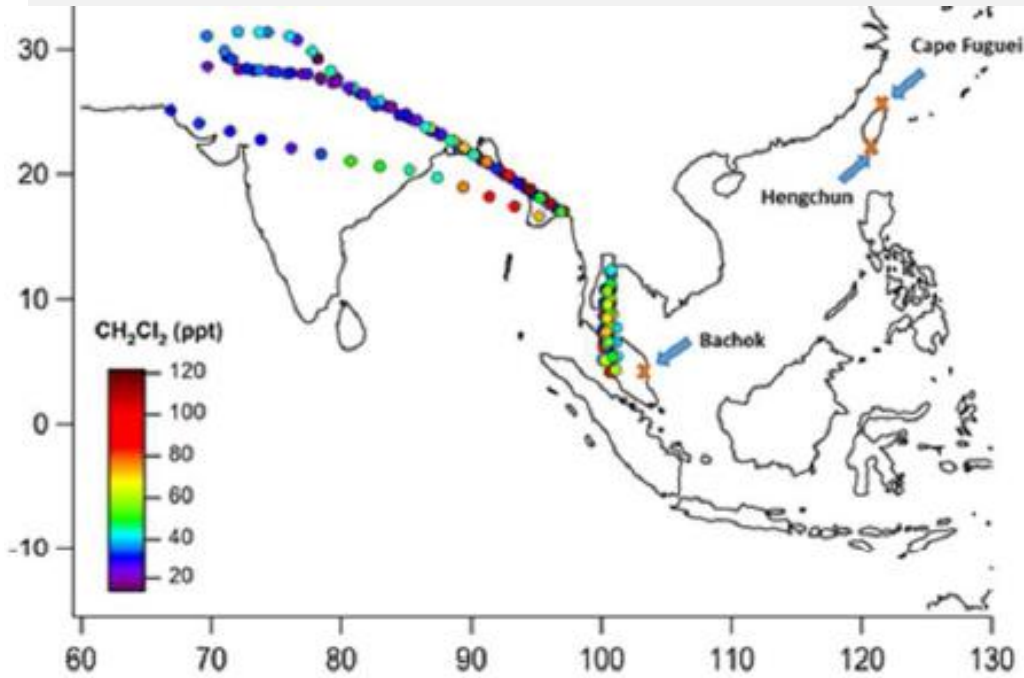


VSLs-Cl measurements in P. Malaysia



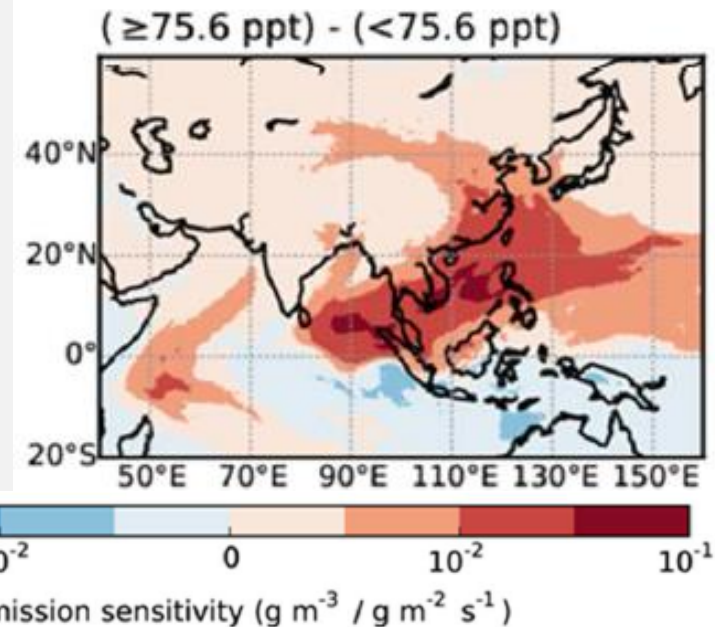
Oram, Ashfold et al., submitted manuscript

VSLs-Cl measurements in upper troposphere



- Further high VSLs-Cl values above SE Asia

- High Cl air masses last at surface in SCS

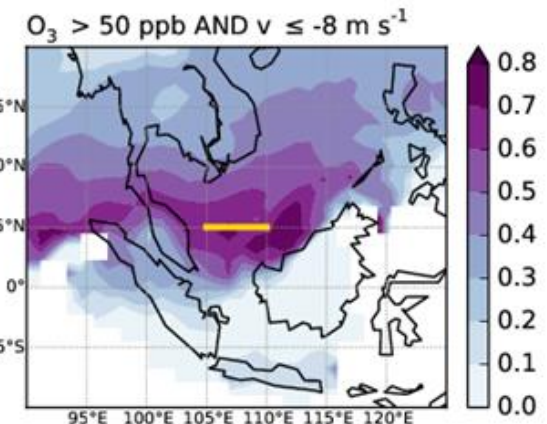
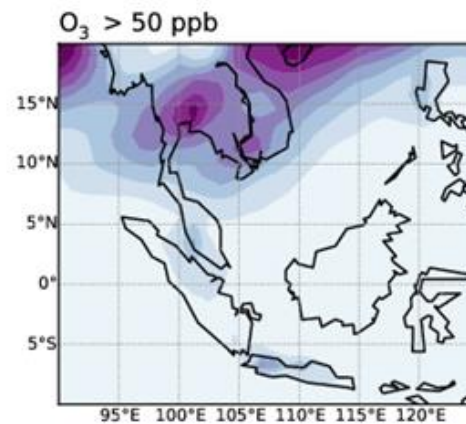
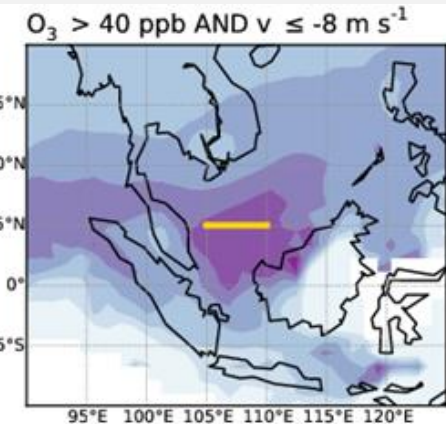
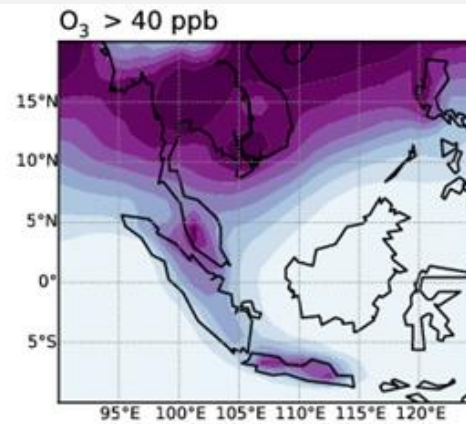
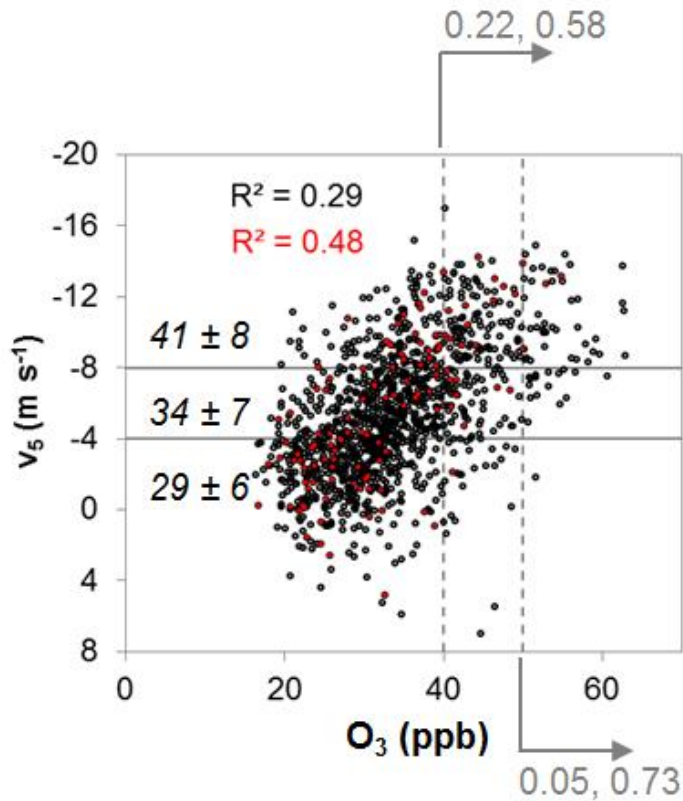




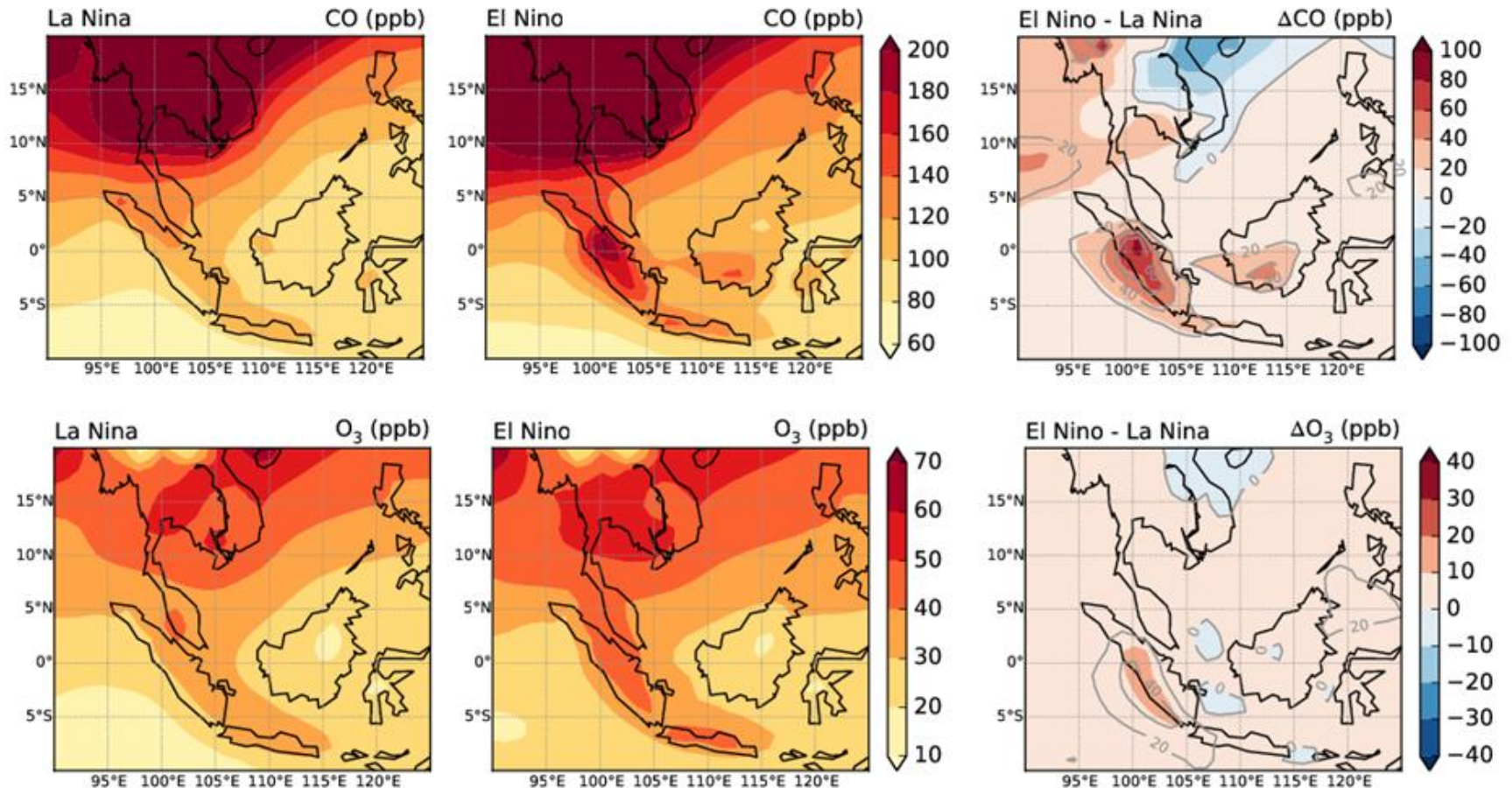
Summary

- The impact of East Asian pollution on SE Asia during NH winter is regional in scale and occurs each year
 - Though likely some ENSO-related variation
- Exceedances of 50 ppb of O₃ (in MACCRA) in much of the region are linked to cold surges
 - Need for less locally influenced observations?
- East Asian sources also linked to very high levels of VSLs-Cl in the SE Asian upper troposphere
 - Stratospheric input remains uncertain

Exceedances of O₃ thresholds

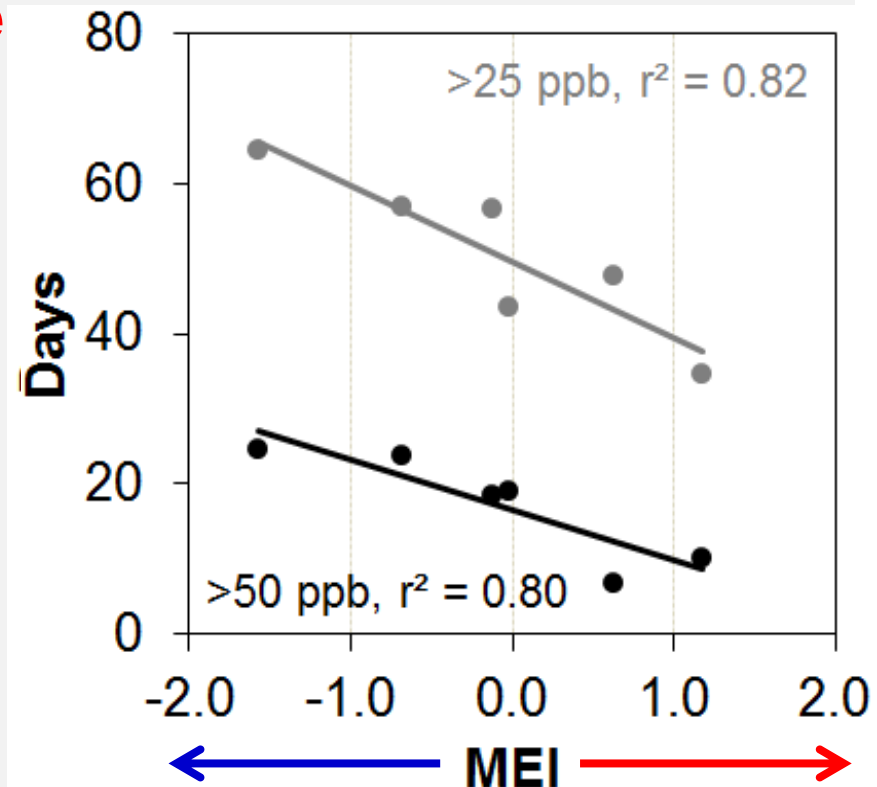


ENSO-related variations



Does this type of transport vary with year?

- Consider NAME **mid-latitude industrial CO tracer**
- At Bachok in winter 13/14:
 - 57 days >25 ppb CO
 - 19 days >50 ppb CO
- Plot against an ENSO index
- Include 5 other recent winters...





Extra: inter-annual variability

- Number of days with modelled CO above a certain threshold

NH winter	> 25 ppb	>50 ppb	>100 ppb	MEI* (De-Ja)	MEI* (Oc-Ap)
2009/10	35	10	0.3	1.2	1.2
2010/11	64	25	0.9	-1.7	-1.6
2011/12	57	24	2.6	-1.0	-0.7
2012/13	44	19	2.9	0.0	0.0
2013/14	57	19	1.0	-0.3	-0.1
2014/15	48	7	0.0	0.4	0.6

How are other parts of SE Asia affected?

- Observations of C_2Cl_4 in **Bachok, Peninsular Malaysia**
- A **mid-latitude industrial carbon monoxide tracer** in NAME co-varies with these observations

