

# Evaluating the seasonal cycle of tropospheric ozone in global models

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BSc(Hons) 2i Geophysics**

# Ozone is a key gas for air quality and climate

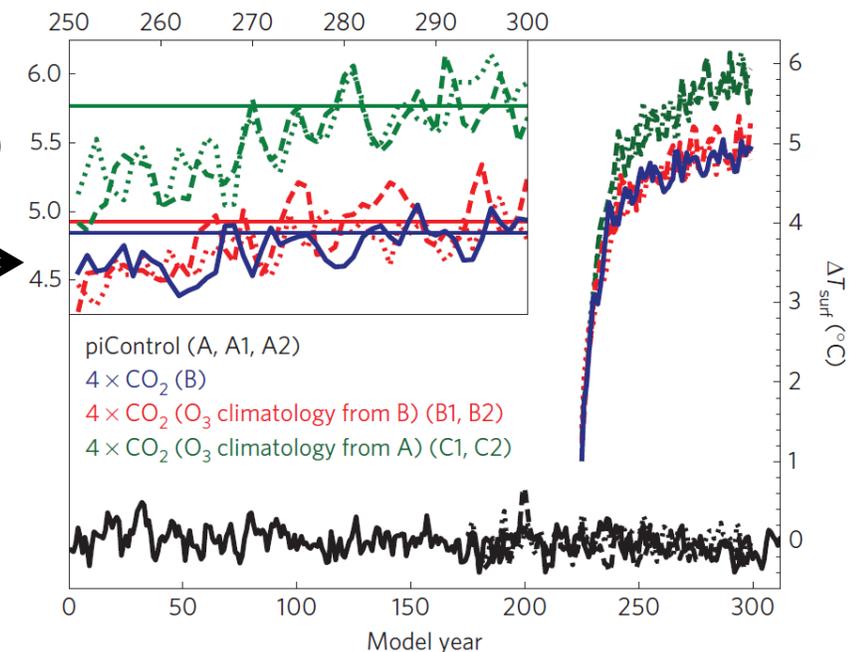
- 👤 Responsible for an estimated ~800,000 deaths per year (WHO, 2014)
- 👤 Damage to crops\* estimated at ~US\$14-26 bn/yr (Royal Society, 2008)

\*rice, soybean, maize and wheat

- 👤 Radiative forcing ~0.4 W m<sup>-2</sup> since 1750 (IPCC, 2013)

- 👤 Including interactive ozone in HadGEM2 reduced equilibrium climate sensitivity by 20% (Nowack et al., 2015, Nature Climate Change)

- 👤 So we'd like models to accurately simulate ozone...



# Ozone and meteorology are strongly coupled

Models indicate a global mean tropospheric ozone lifetime of ~20 days (shorter towards surface & equator).  
 ⇒ Strong coupling between meteorological processes and ozone chemistry

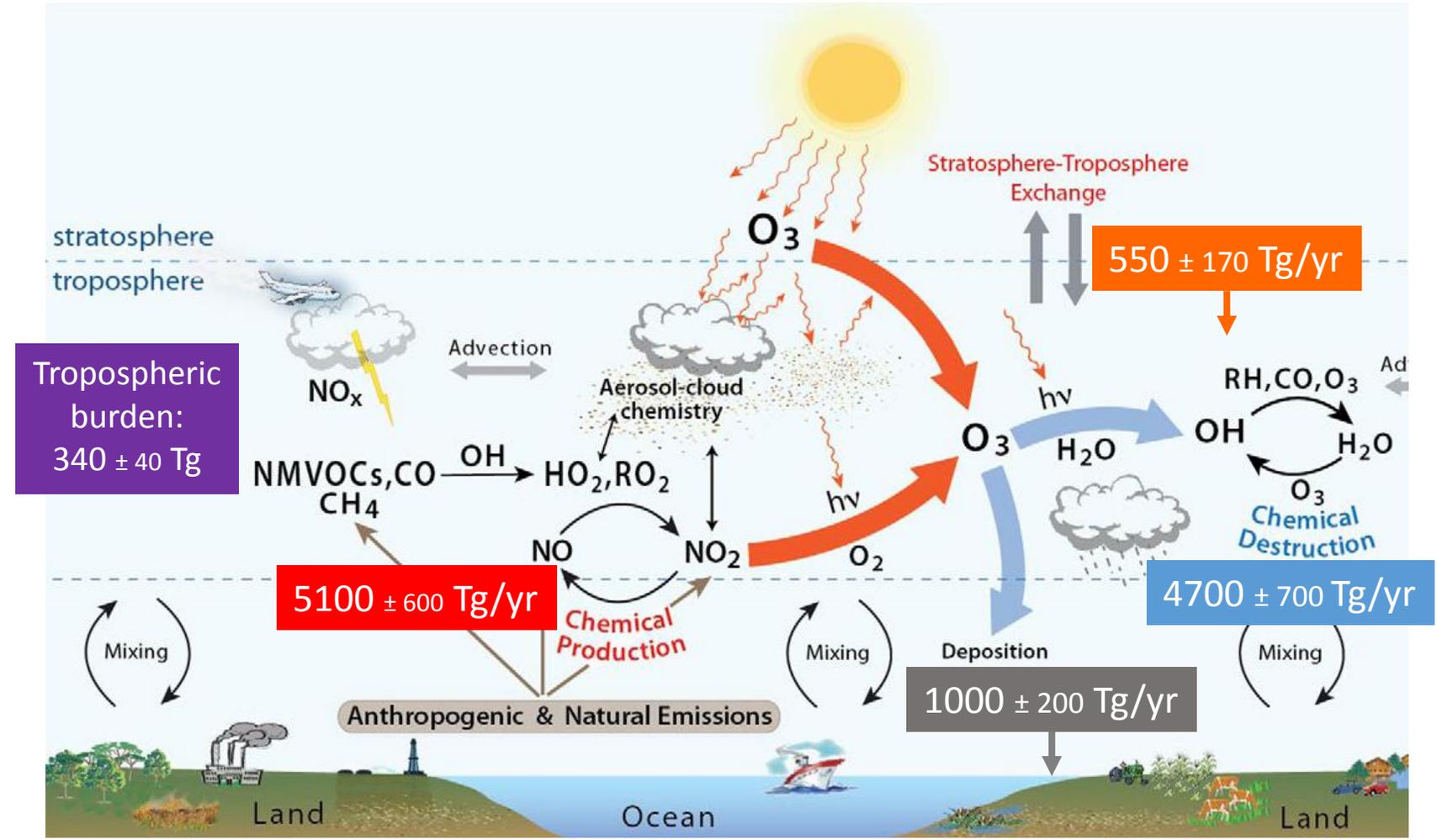
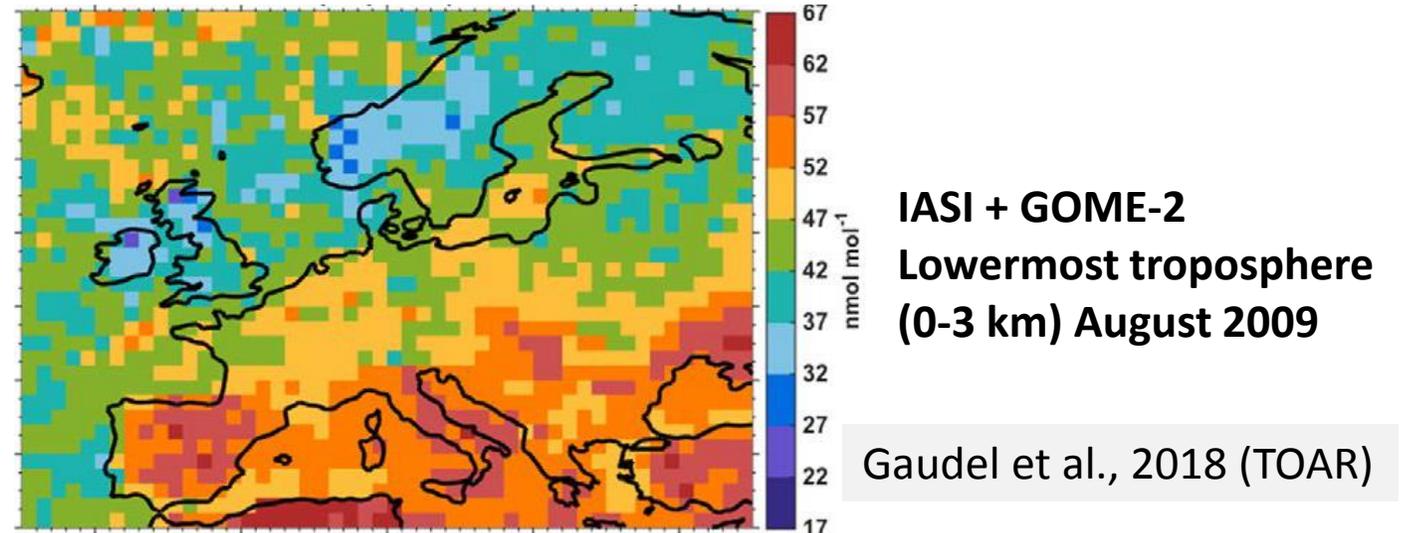
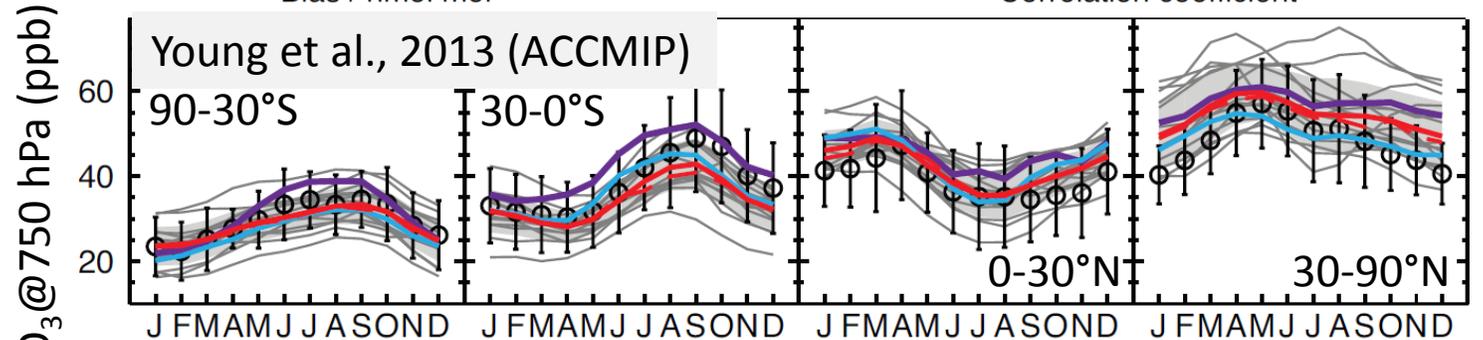
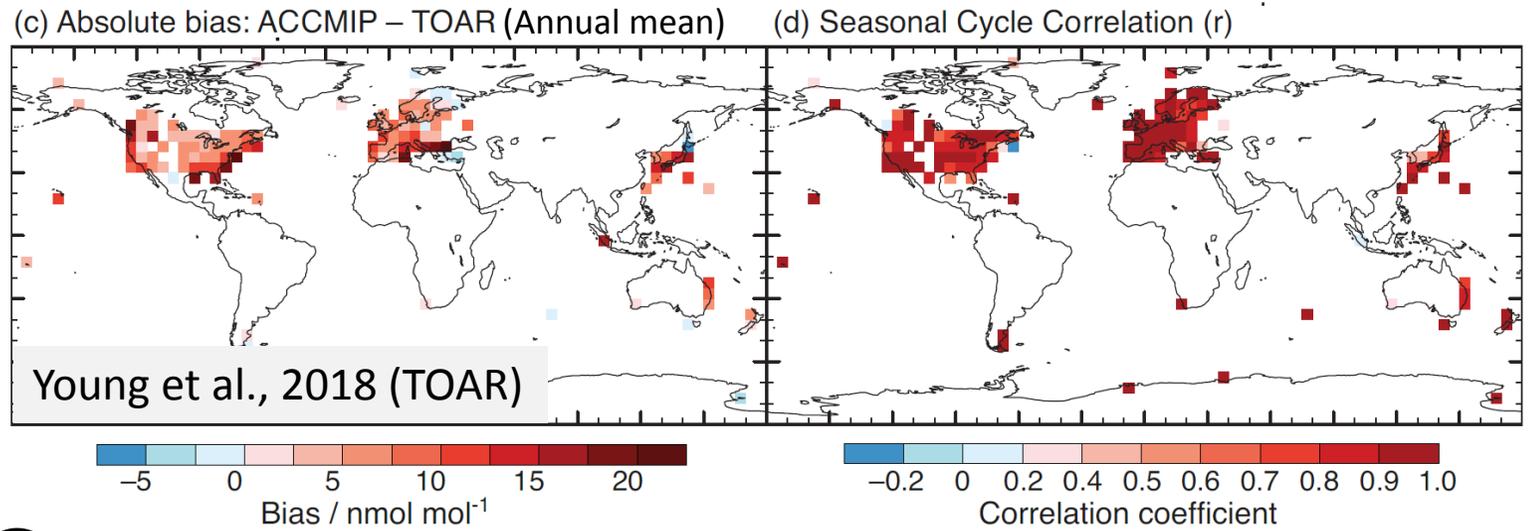


Figure from Young et al. (2018) TOAR  
 Budget values from Stevenson et al. (2006) ACCENT multi-model mean

# How do we currently evaluate modelled tropospheric ozone?

- Surface stations
- Ozone-sondes
- Aircraft (in-service & research campaigns)
  - MOZAIC, IAGOS, etc.
- Satellite (tropospheric residual/limited vertical resolution)



# What controls the surface ozone seasonal cycle at a particular location?

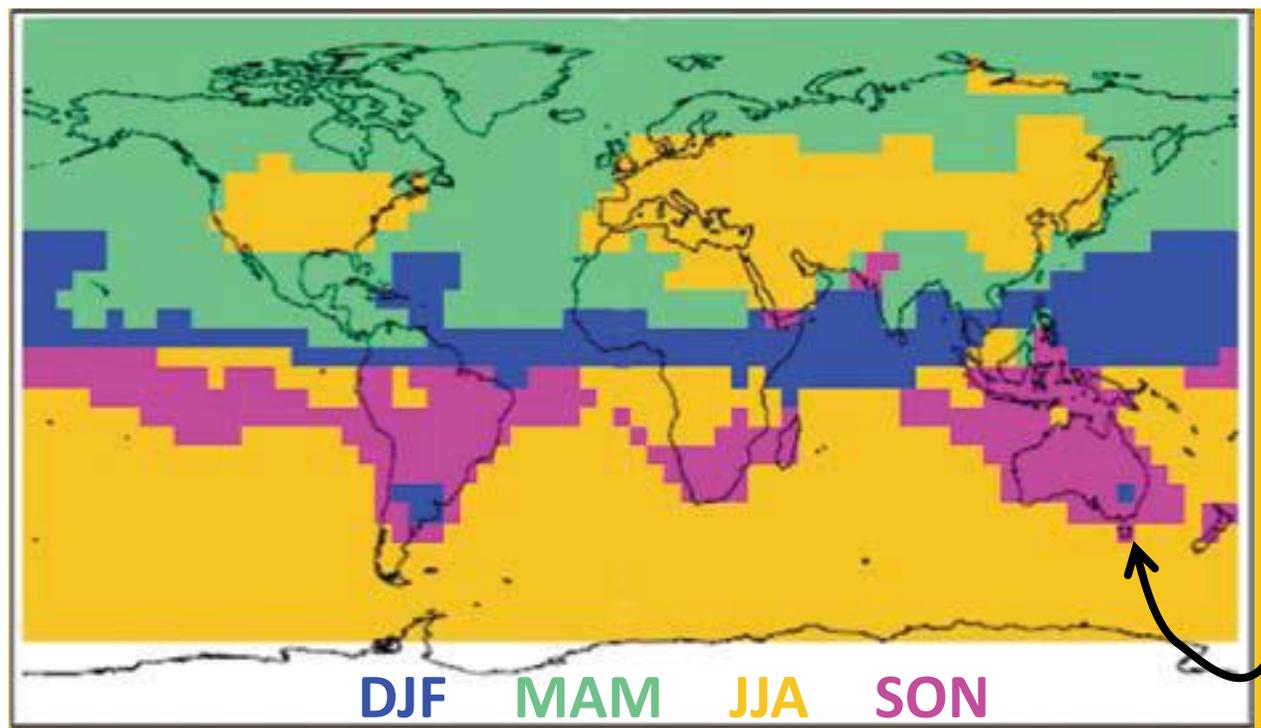
Seasonal variations in:

- Emissions (anthropogenic and natural) of ozone precursors
- Photochemical production/destruction
- Dry deposition (mainly via variations in vegetation)
- Import of ozone and precursors from surroundings -  
e.g., via stratosphere-troposphere exchange, long-range transport

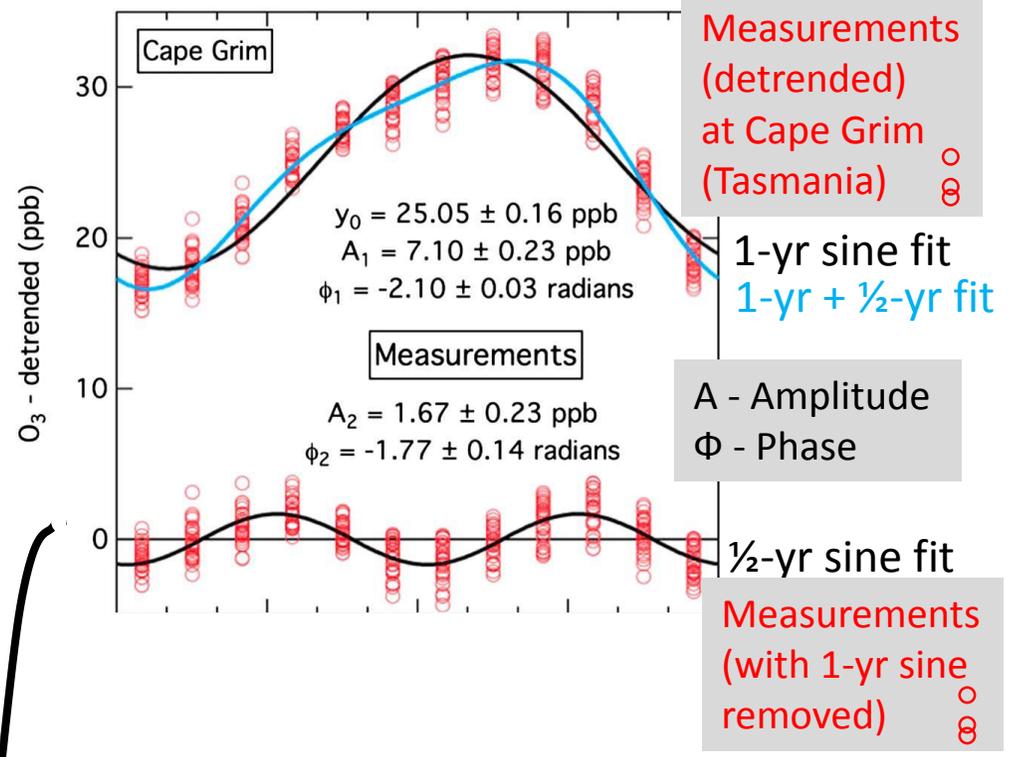
Some locations have strong local influences that dominate  
e.g., sites with high levels of local NO<sub>x</sub> or hydrocarbon emissions

Other locations dominated by regional/hemispheric scale processes  
e.g., sites remote from emissions

# Seasonal cycle of surface ozone



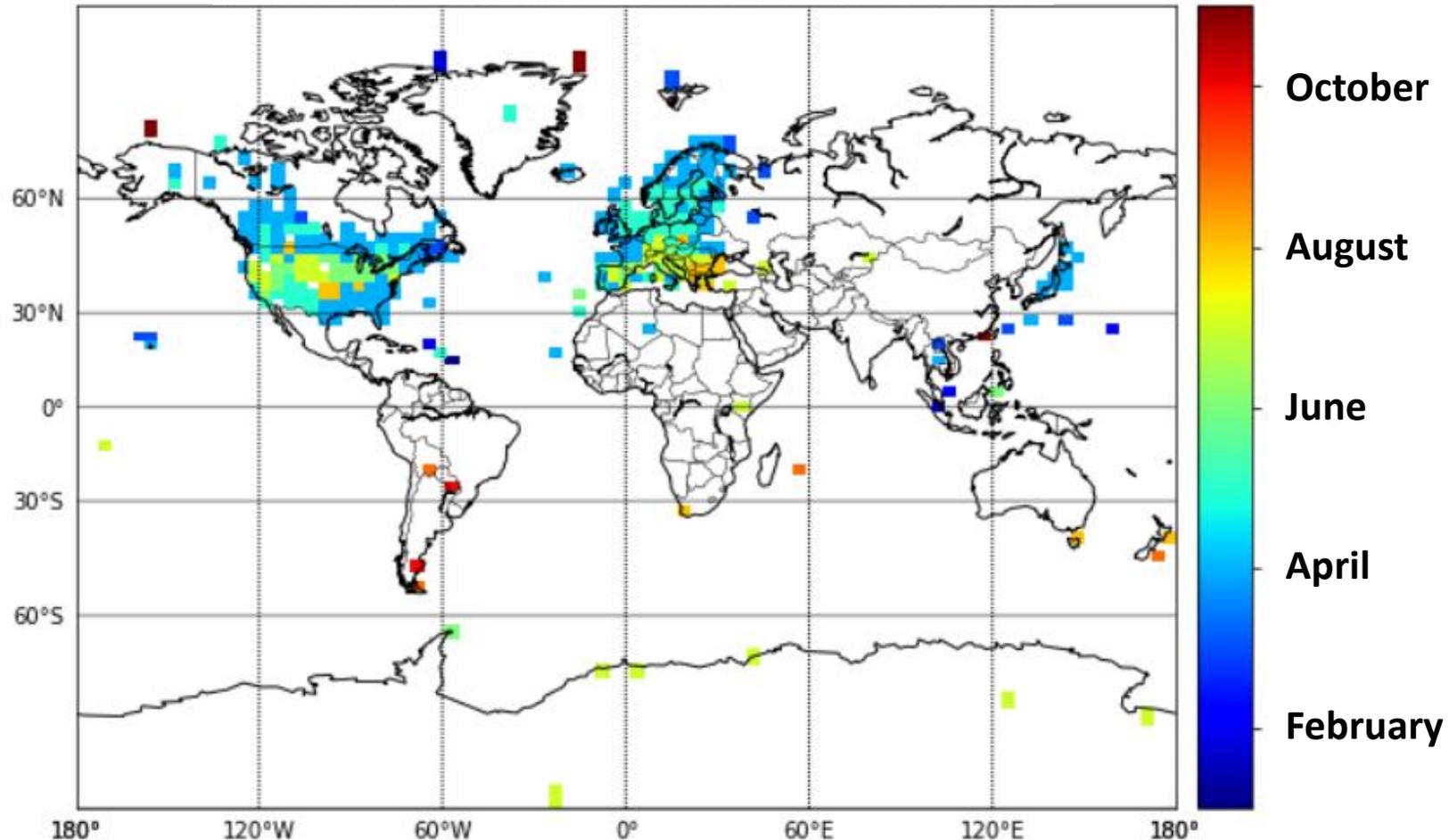
Royal Society (2008) - Multi-model mean



Parrish et al. (2016)

# Surface network synthesis: Sofen et al., 2016

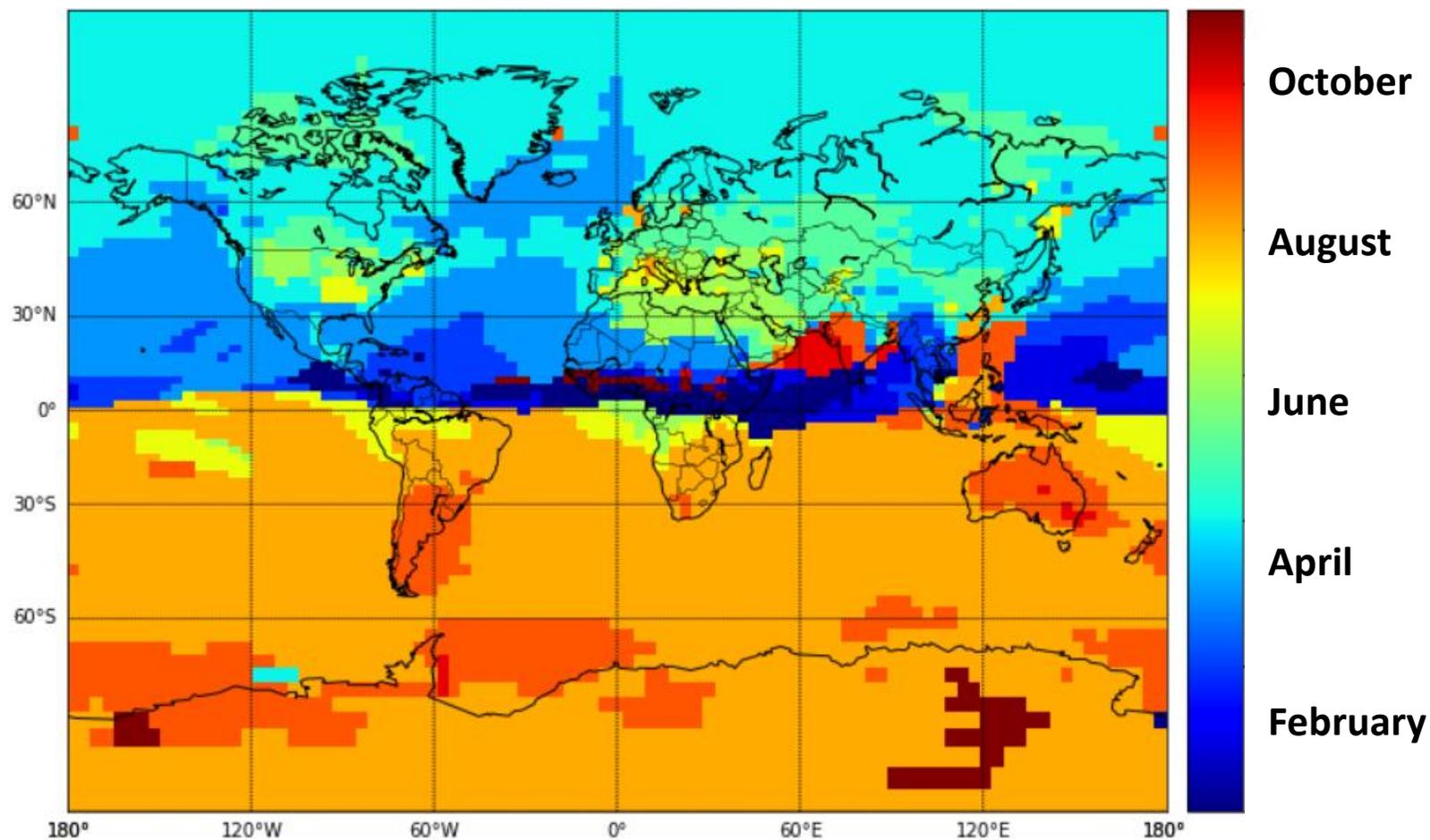
Month of peak surface ozone (observed)



Data binned  
to UKCA  
model grid  
(3.75° x 2.5°)

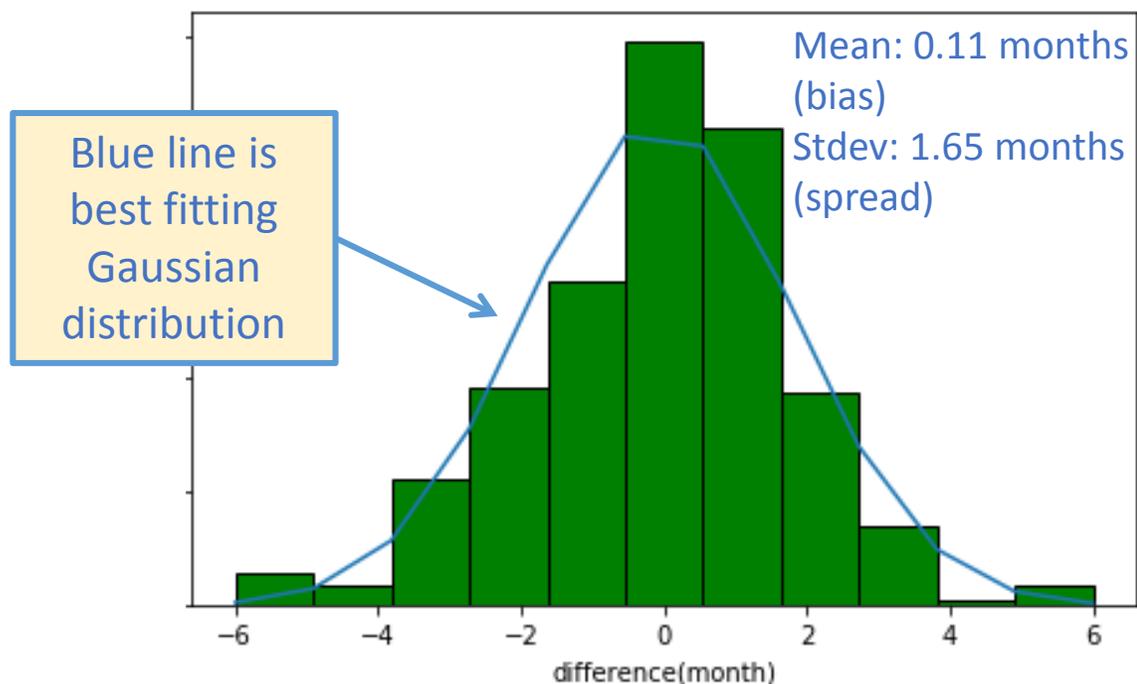
# Model results from UKCA (ACCMIP data)

Month of peak surface ozone (UKCA model)

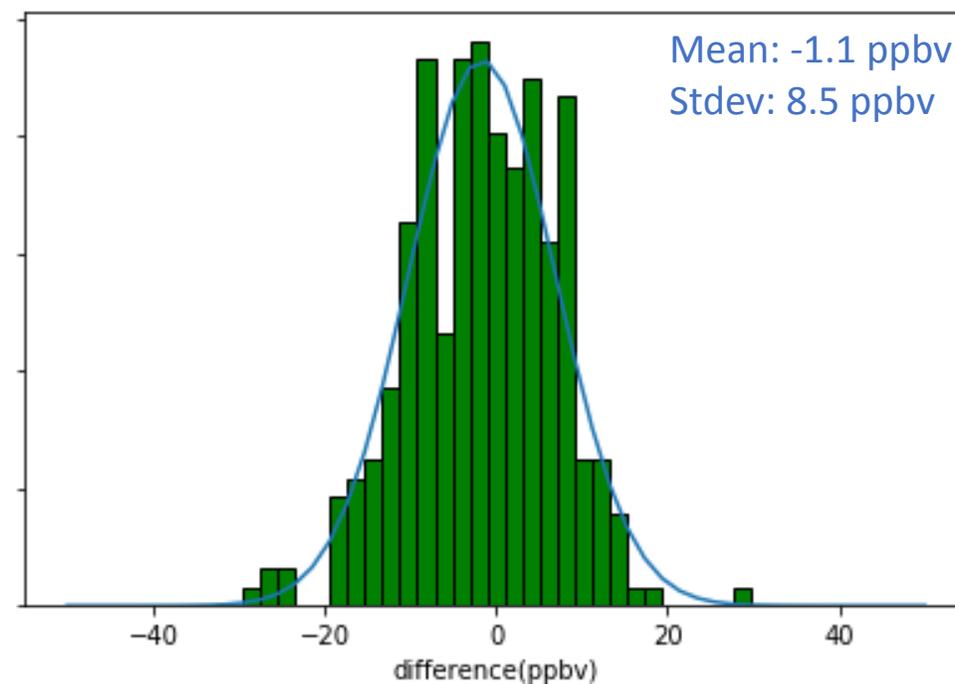


# A useful summary metric for model evaluation?

Peak month difference  
(UKCA - observations)

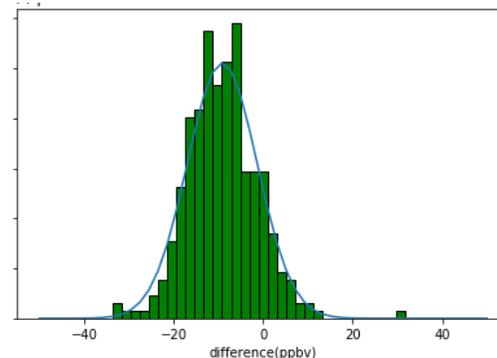
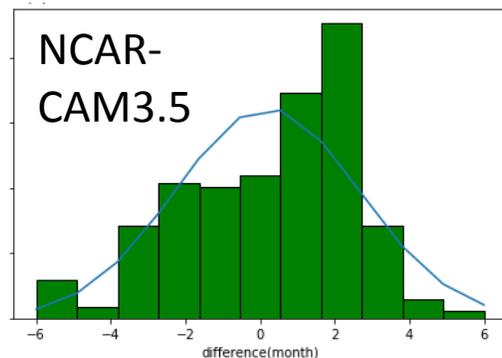
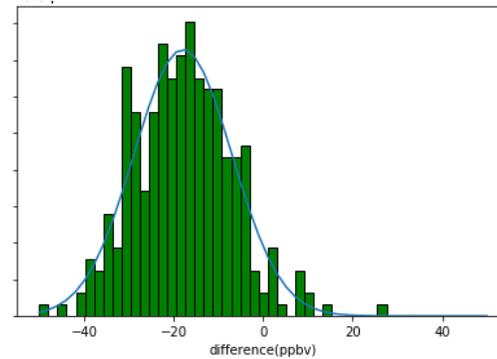
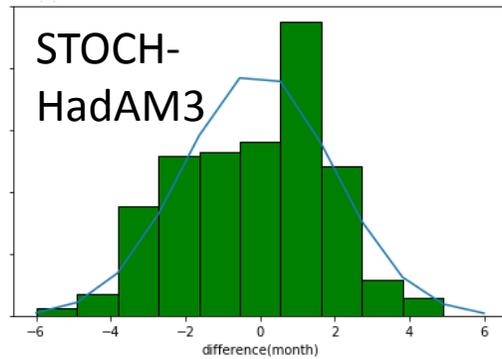
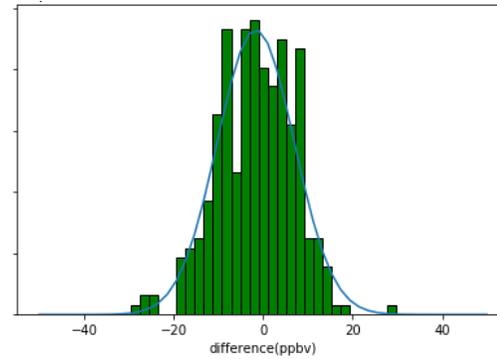
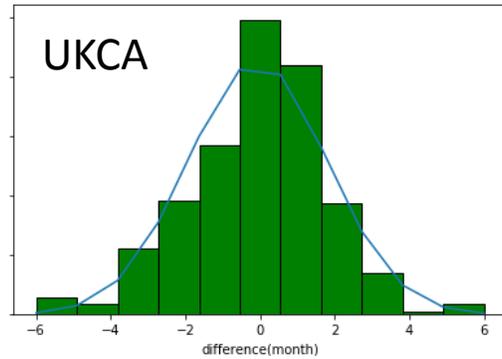


Peak month ozone (ppbv) difference  
(UKCA - observations)



Using all model grid squares with observations  
(i.e. currently very much biased towards sampling N. America & Europe)

# Comparing three ACCMIP models



Model	Peak month timing (months)		Peak month value (ppbv)	
	Bias	Spread	Bias	Spread
UKCA	0.11	1.65	-1.1	8.5
STOCH-HadAM3	-0.05	2.02	-17.9	11.0
NCAR-CAM3.5	0.19	2.47	-9.1	7.8

# Possible future steps

- 👤 Extend to all ACCMIP models/more recent inter-comparisons
- 👤 Extend/update observational data (TOAR database, sondes, aircraft, satellites, etc.)
- 👤 Produce regional metrics (Europe, N. America, etc.)
- 👤 Compare amplitude/phase of seasonal (and sub-seasonal)cycles, not just peak month/concentrations (cf. Parrish et al., 2016)
- 👤 Look at changes in seasonal cycle over time (cf. Parrish et al., 2013)
- 👤 Also evaluate diurnal cycles? (using hourly data)

# Conclusions

- New metric to evaluate spatial variations in the seasonal cycle of surface ozone
- Metric evaluates models in a new way, perhaps shedding light on some previously unexplored processes
- Metric shows discrimination between models, suggesting it may be a useful addition to other ozone metrics (e.g., global burden)
- Metric has room for improvement, refinement and extension
- This is work in progress, happy to discuss
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