Understanding Ozone

Focus on surface ozone trends in Europe

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Workshop on air quality policy implementation related to ozone, Madrid, Spain

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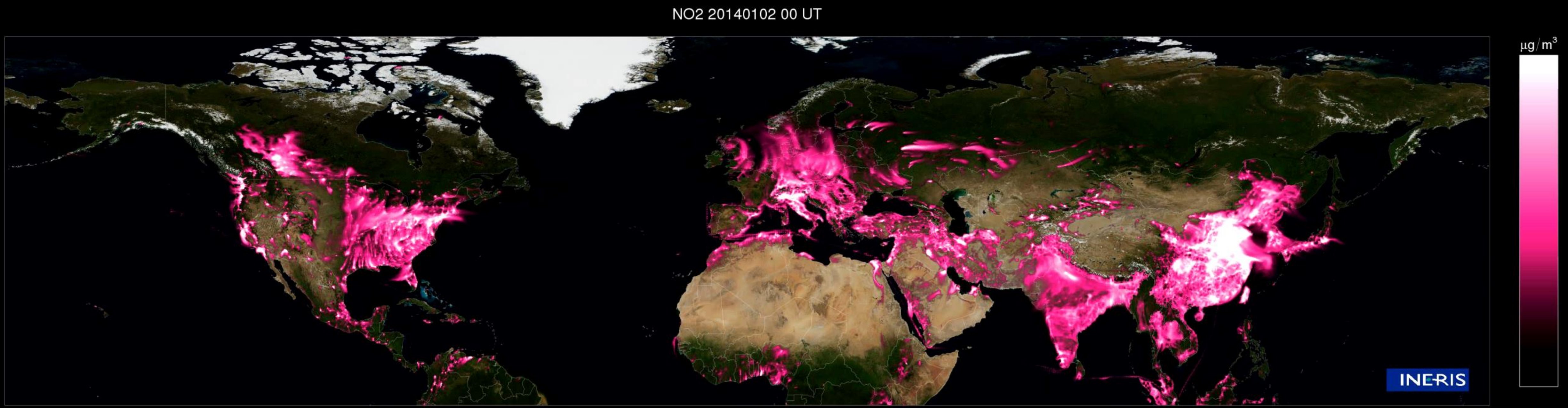
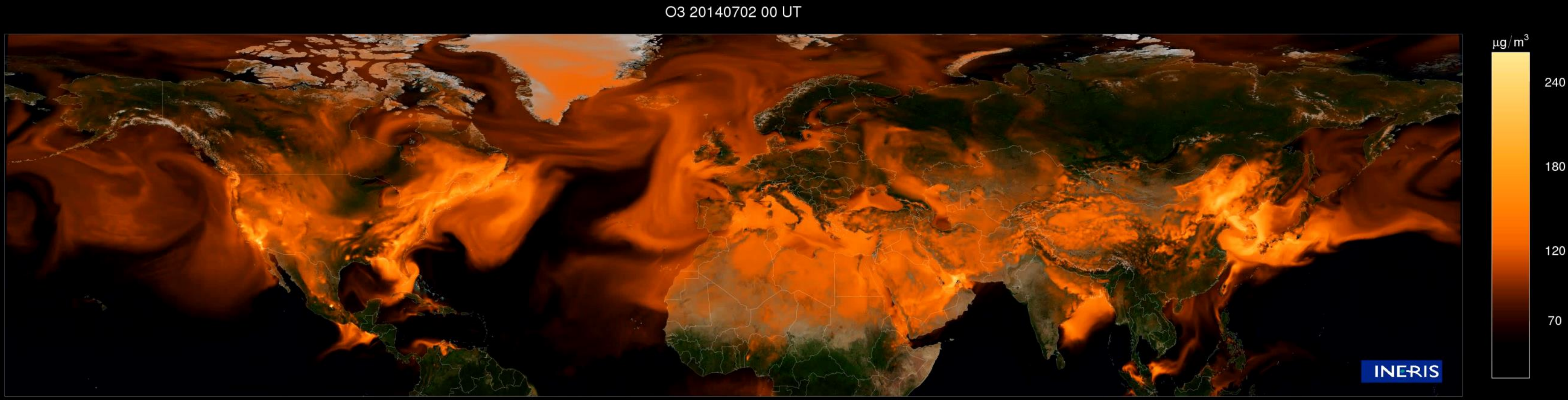


Nitrogen dioxyde (NO_2) in the Northern Hemisphere
CHIMERE Air Quality Model Simulations, 10km resolution



Ozone (O_3) in the Northern Hemisphere
CHIMERE Air Quality Model Simulations, 10km resolution

Tropospheric Ozone Chemistry

- Ozone (O_3) photochemical production in the troposphere occurs by
  - hydroxyl radical (OH) oxidation of carbon monoxide (CO), methane (CH4) and non-methane hydrocarbons (NMHC)
  - in the presence of nitrogen oxides (NOx).

Table 1

Tropospheric ozone budget from ACCMIP comparison [9•]. Fifteen models used for burden, six for other terms, data represent year 2000. ± represents one standard deviation

Burden (Tg)	337 ± 23
Transport from stratosphere (Tg/year)	477 ± 96
Chemical production — troposphere (Tg/year)	4877 ± 853
Chemical loss (Tg/year)	4260 ± 645
Deposition (Tg/year)	1094 ± 264
Lifetime (days)	23.4

Simpson et al., COES 2014

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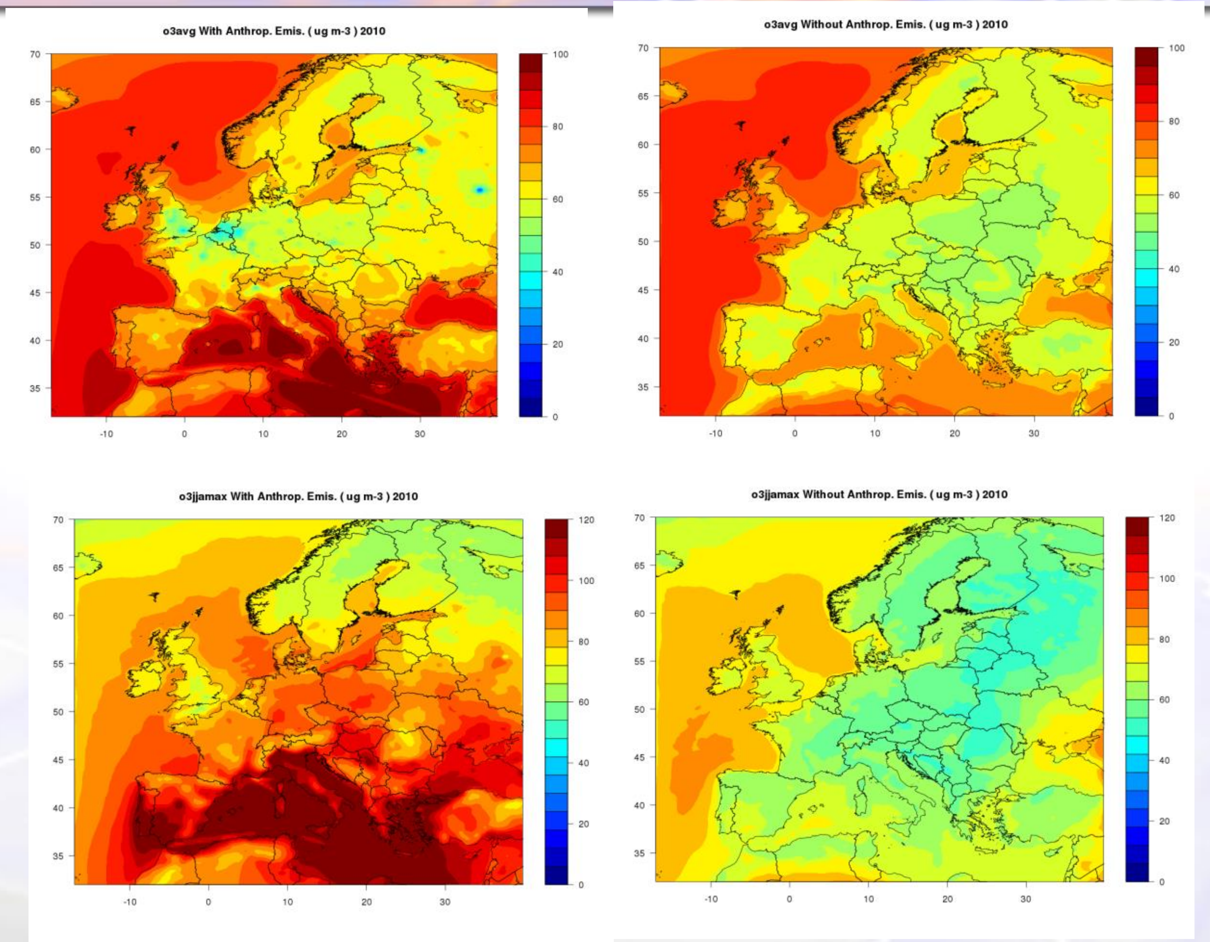
Ozone in a pristine atmosphere

- How European ozone would look like in the absence of Anthropogenic emissions



ETC/ACM 2018

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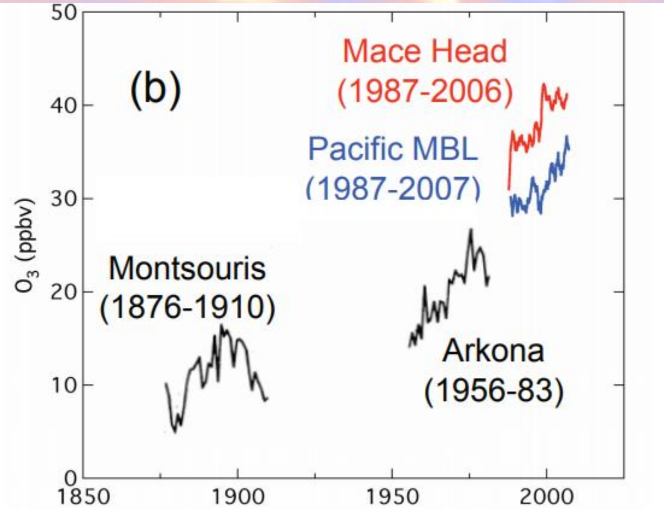
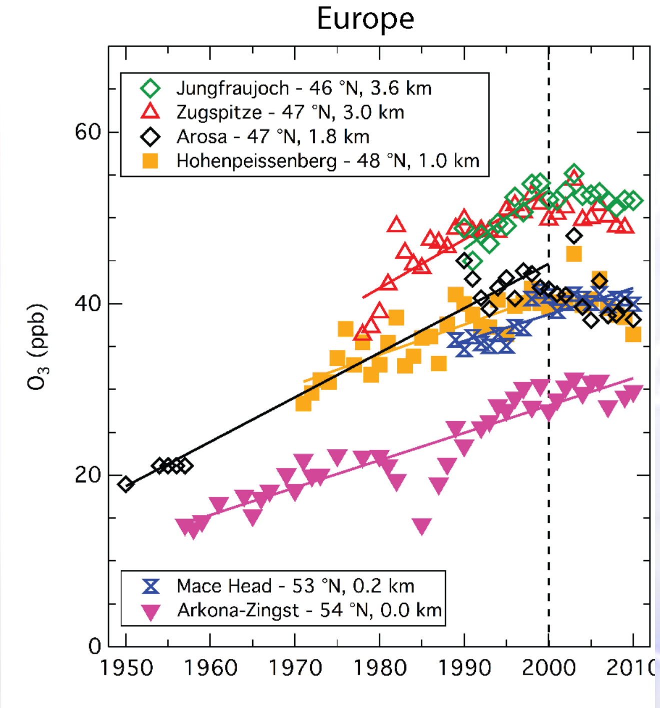
Trends in the 20th century

- Surface tropospheric ozone levels in western Europe increased
  - by a factor of 3–5 between the late 1800s and late 1900s
  - by a factor of 2 between the 1950s and 1990s
- The uncertainty of the measurements is so great that no accurate estimate can be made of the absolute increase in ozone
- All available Northern Hemisphere surface monitoring sites indicate increasing ozone from 1950–1979 until 2000– 2010, with 11 of 13 sites having statistically significant trends
- Most current global models are still unable to reproduce the low surface ozone concentrations (~10ppbv) reliably observed at Montsouris, near Paris, at the end of the 19th century
- References
  - Monks et al. ACP 2015, Cooper et al. Elementa 2014, Parrish et al. ACP 2009

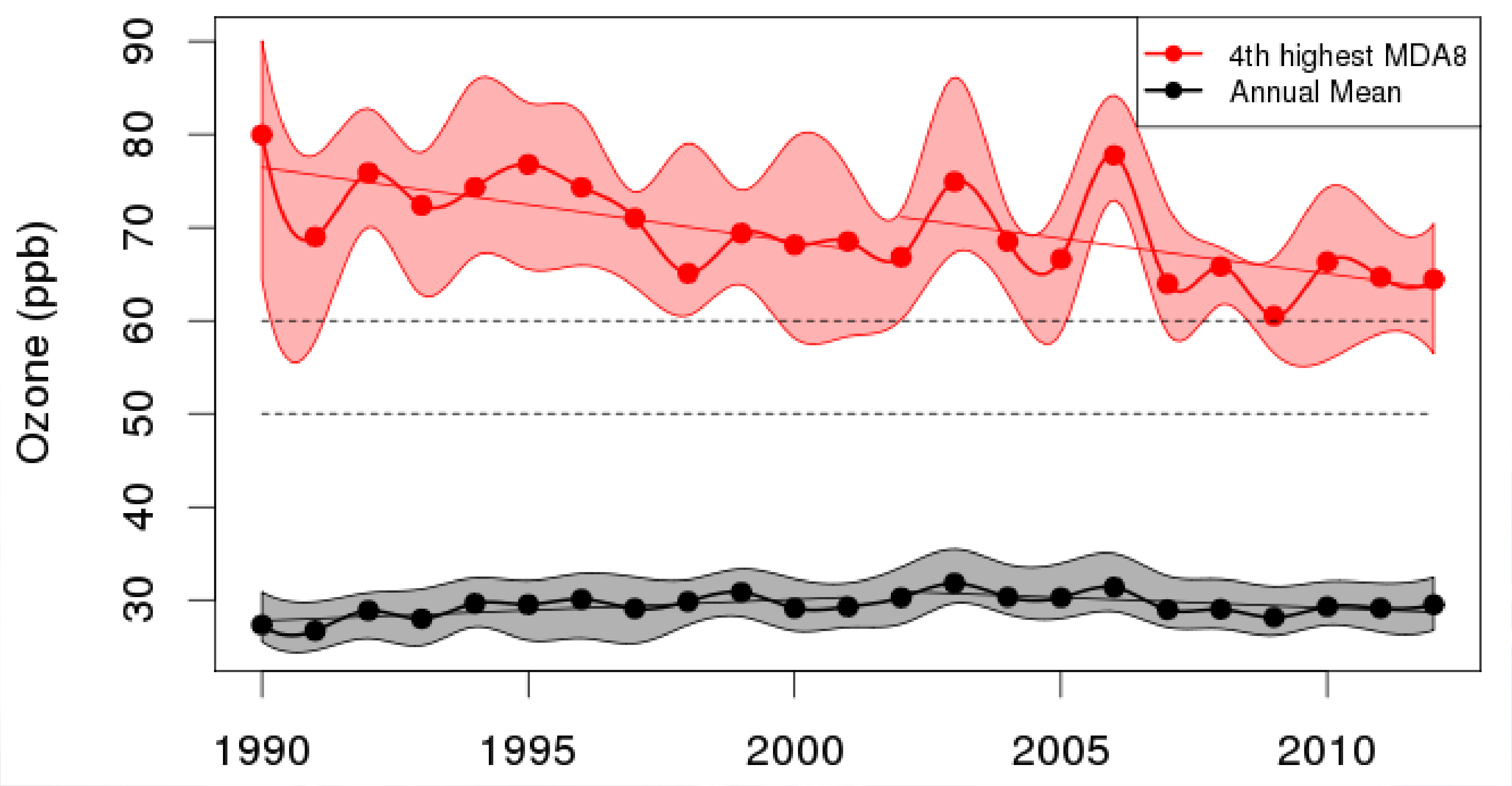


Parrish et al., ACP 200



Cooper et al. Elemen

Recent Trends: 1990-2010



Source: EMEP/TFMM trend report, 2016

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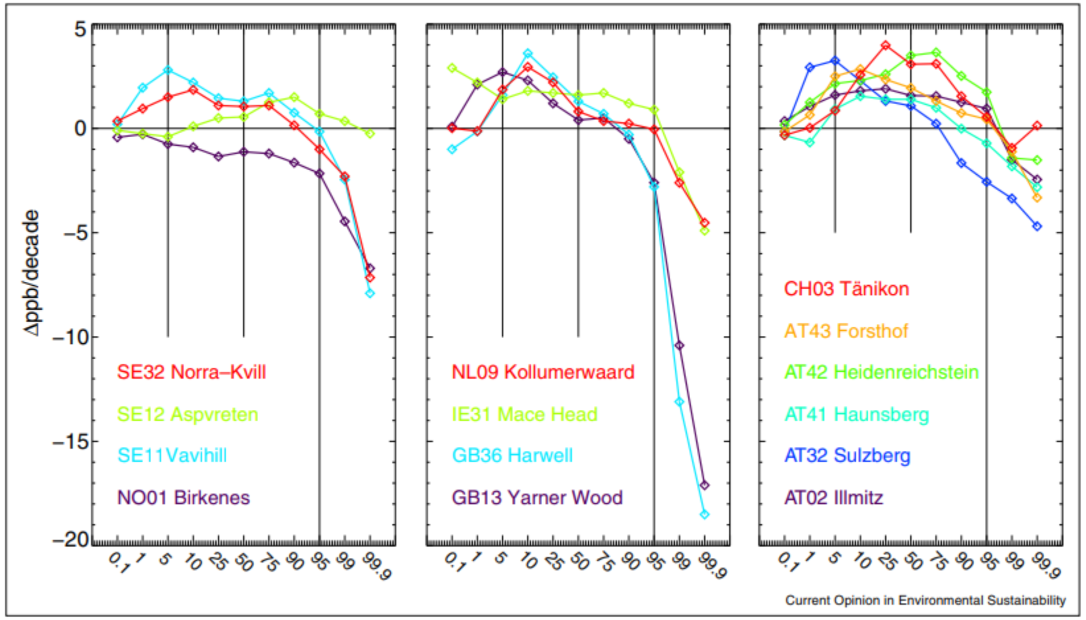
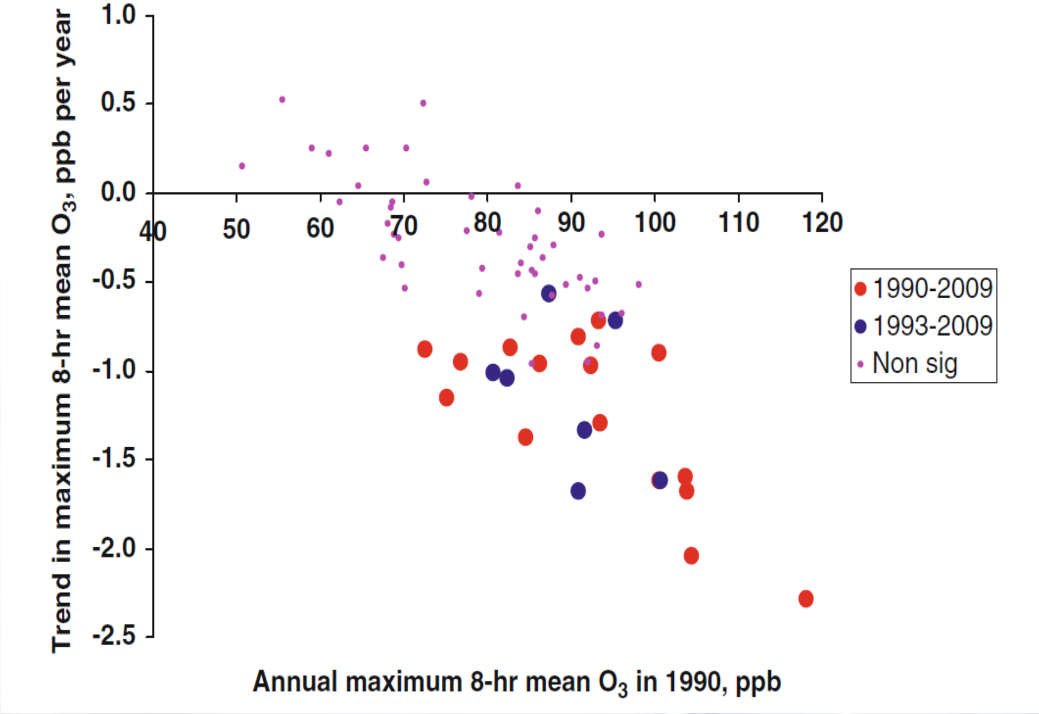
Trends: metrics

- Largest decreases for higher O3 levels
  - For sites with high O3 levels
  - For a single sites: during days of high O3



The change in mean annual percentiles (of hourly ozone data) from the decade 1990–1999 to the decade 2000–2009, that is, *Px*(2000s)-–*Px*(1990s), where *x* ranges from 0.1 to 99.9, for selected European sites. Data and sites from [66*], with a data-capture requirement of 75% completeness of hourly data in each year.



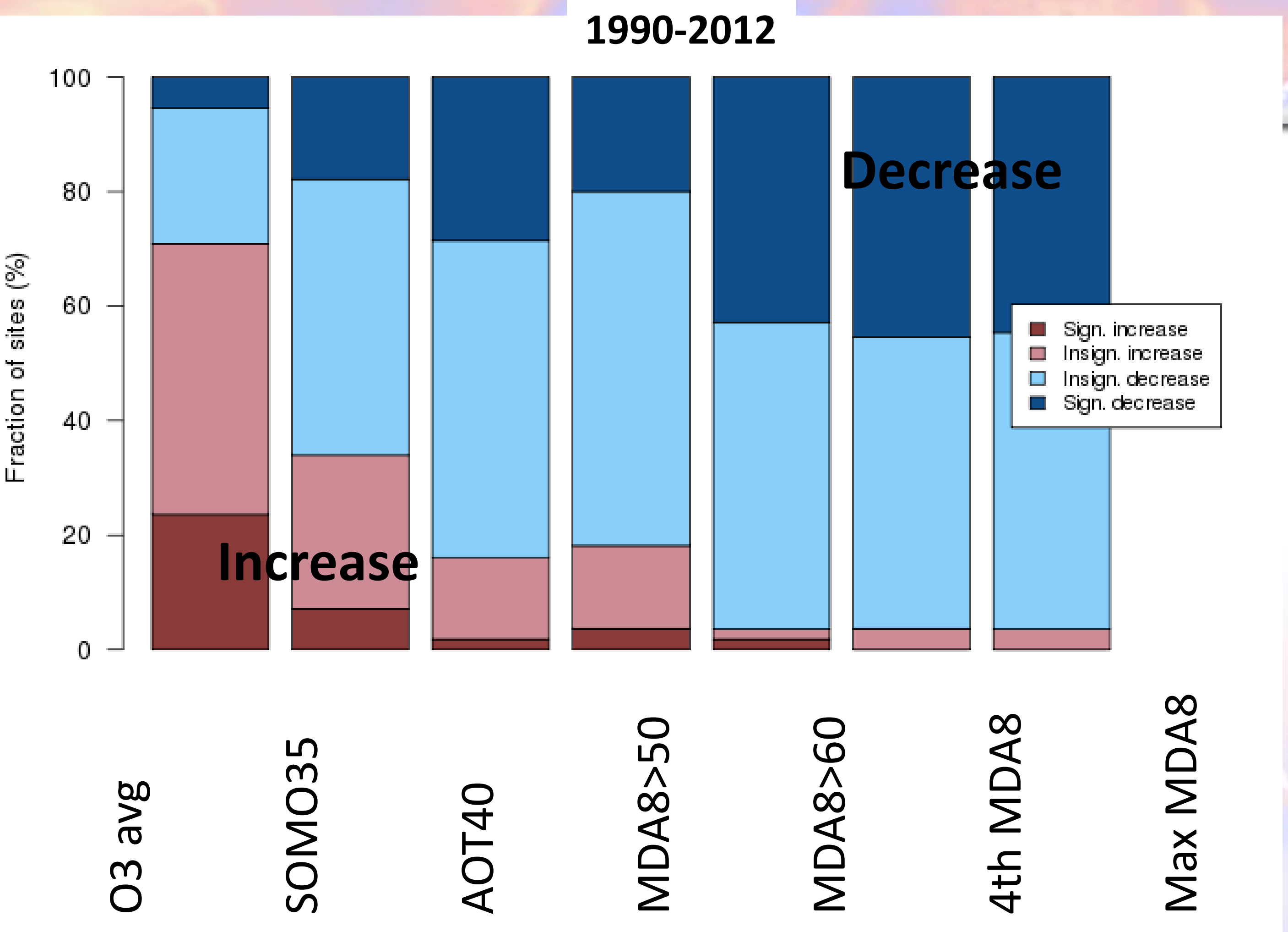
Simpson et al.,
COES 2014

D. Derwent

Trends: metrics

- Sensitivity to metrics
- Importance of non-significant trends

Ozone Metric	% change 1990-2012
Annual mean	+4%
SOMO35	-8%
AOT40	-31%
# days > 100µg/m3	-22%
# days > 120µg/m3	-49%
4th highest MDA8	-12%



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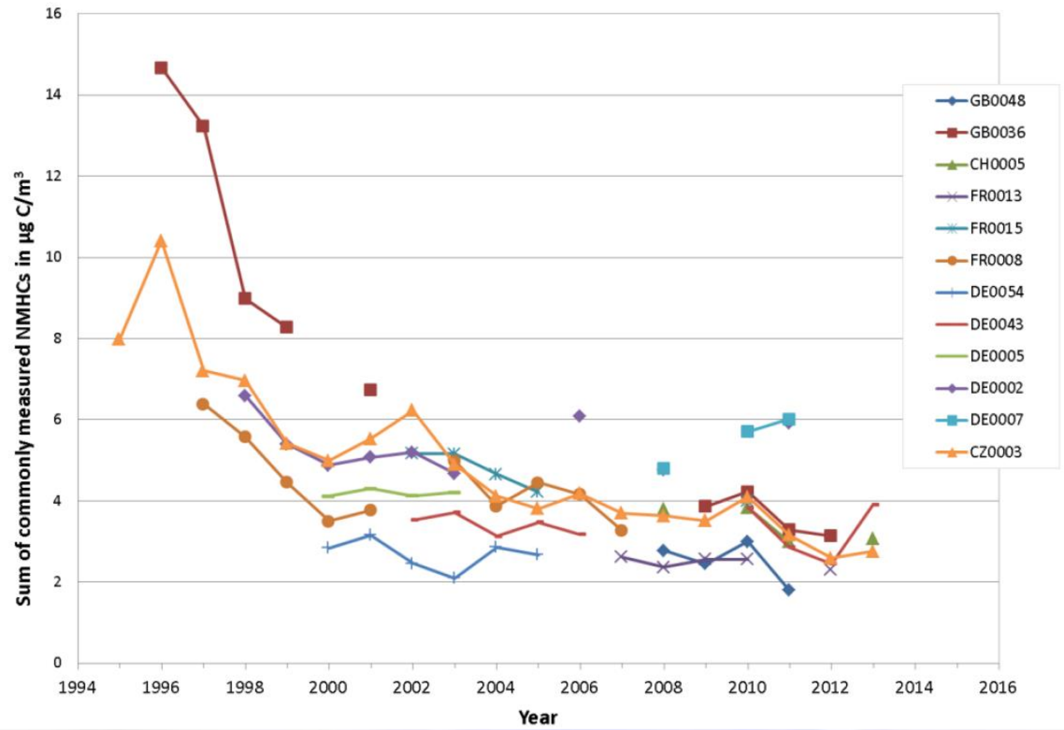
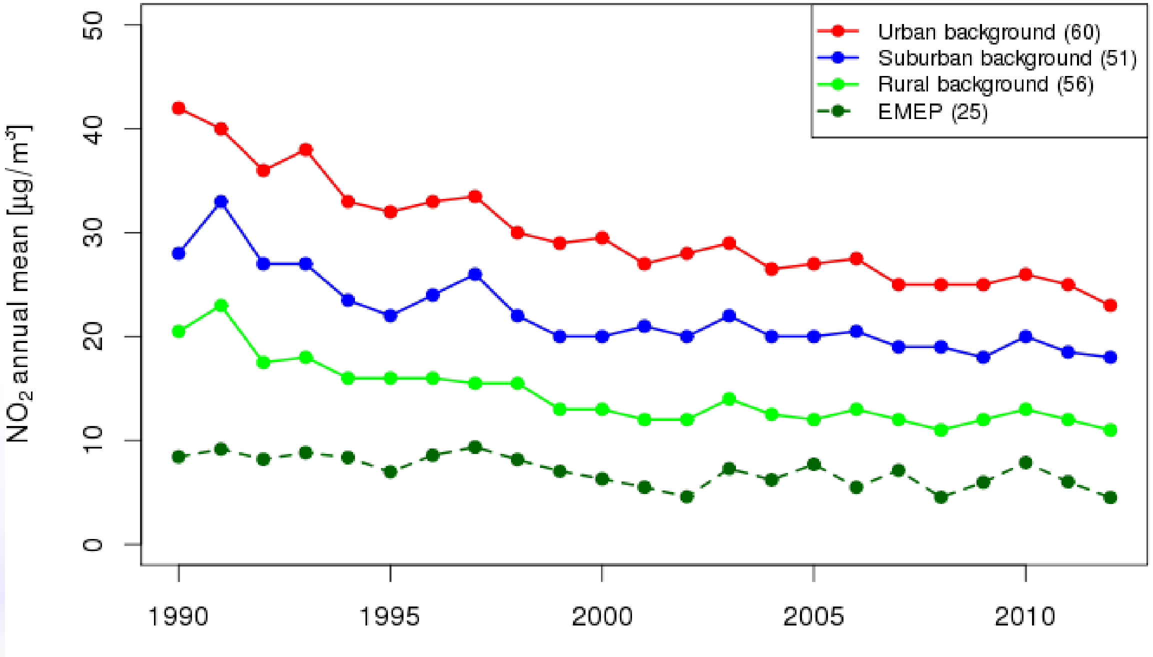
Precursors





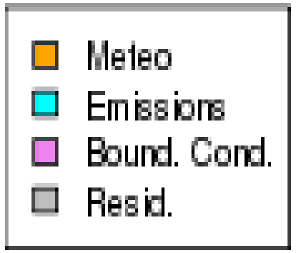
Sum of commonly-measured NMHCs at selected EMEP stations in µgC/m3, shown as annual averages over time periods with available data. NMHCs included in the total are acetylene (ethyne), benzene, i-butane, n-butane, ethylene, hexane, i-pentane, n-pentane, propene, and toluene. For more information about the selection of NMHC data

Over the 2002-2012 period, a decrease of 40% is found, which is in line with the 31% relative reduction of reported NMVOC emissions for the 2002-2012 period.

TFMM Trend report, 2016

Over the full 23-year period between 1990 and 2012, the average relative NO2 reduction based on the Sen-Theil slope is very consistent at EMEP (39%) and AIRBASE rural background (41%) sites. The relative reduction is 39% at urban sites, which is slightly smaller than the 51% decline in reported NOx emissions over EU between 1990 and 2012.

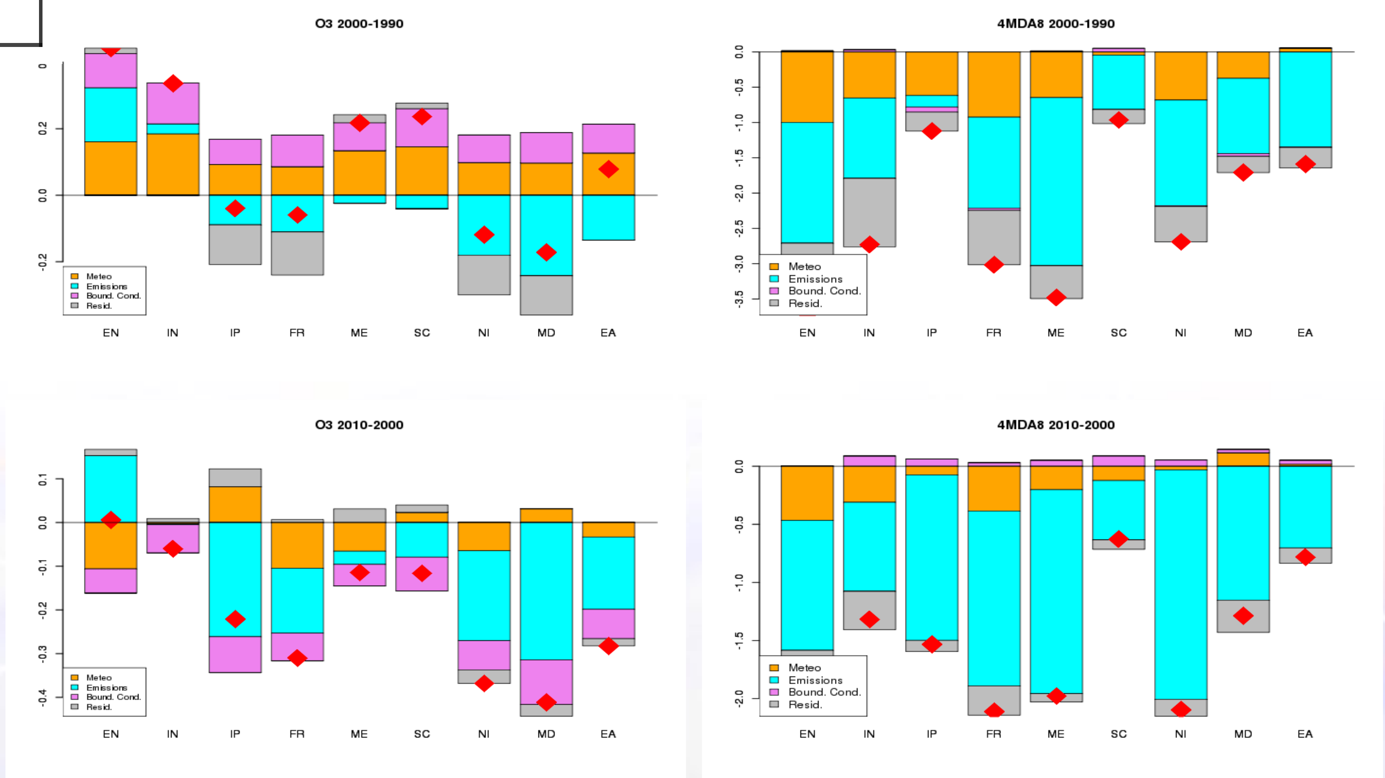
Trends: attribution



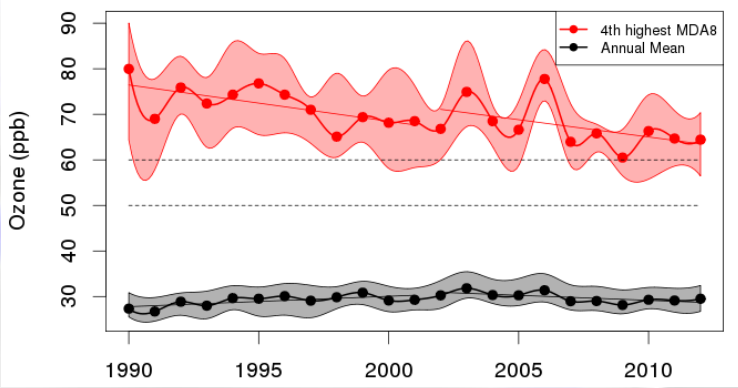
- Eurodelta-Trends
- TFMM
  - Chimere, CMAQ, Emep, Lotos-Euros, Match, Minni, Polyphemus, WRF-Chem

O3avg

O3 4MDA8

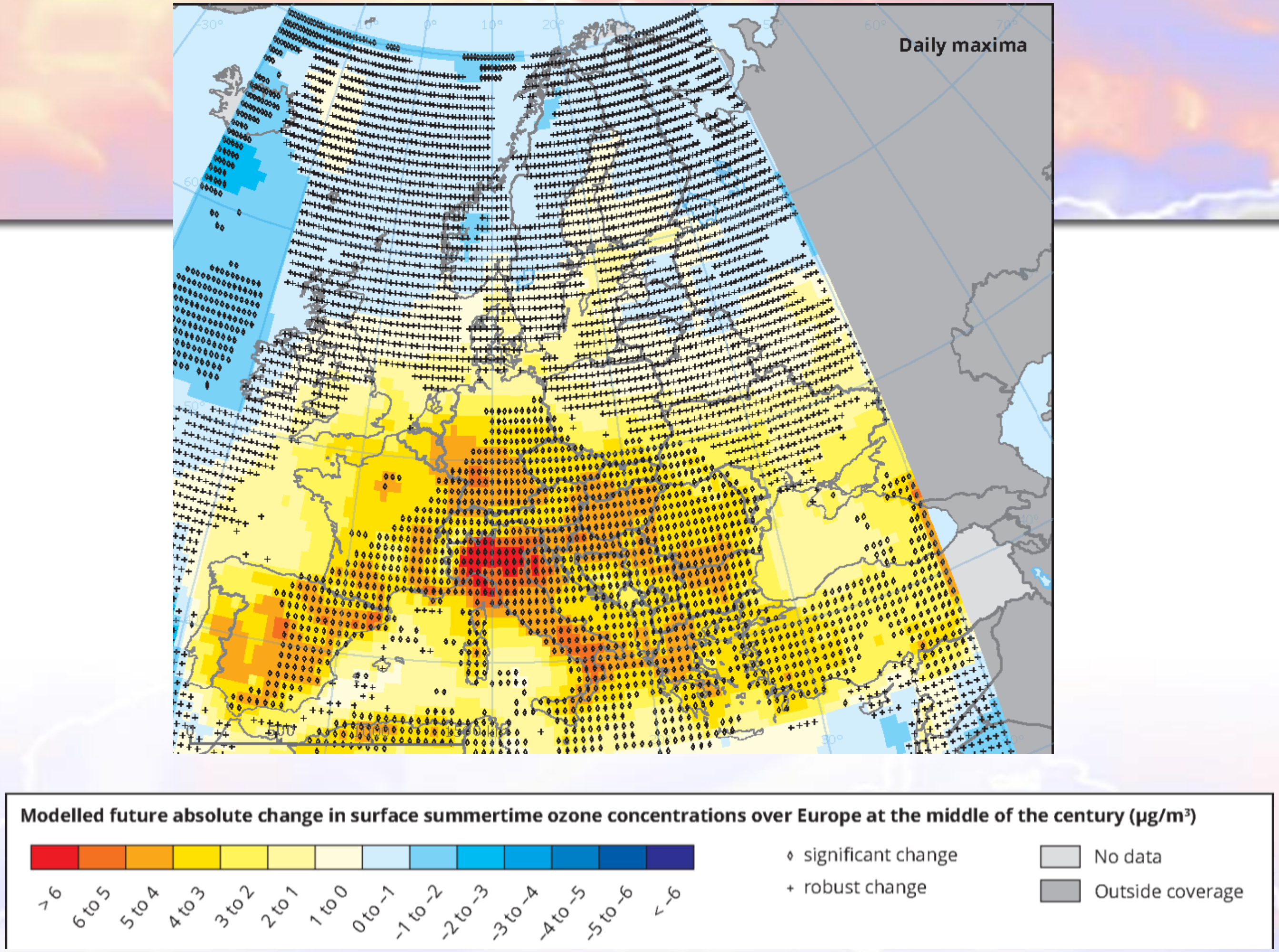


ETC/ACM Tech Report, 2016
EEA AQ Report, 2018



Climate change penalty

- meta-analysis based on all published experiments up to 2014
- A few ppb for JJA : same magnitude as trend over past 20yrs
- Uncertainties remain for exposure metrics (not modelled)



http://www.eea.europa.eu/data-and-maps/indicators/air-pollution-by-ozone-2/assessment

Colette et al., ERL, 2015

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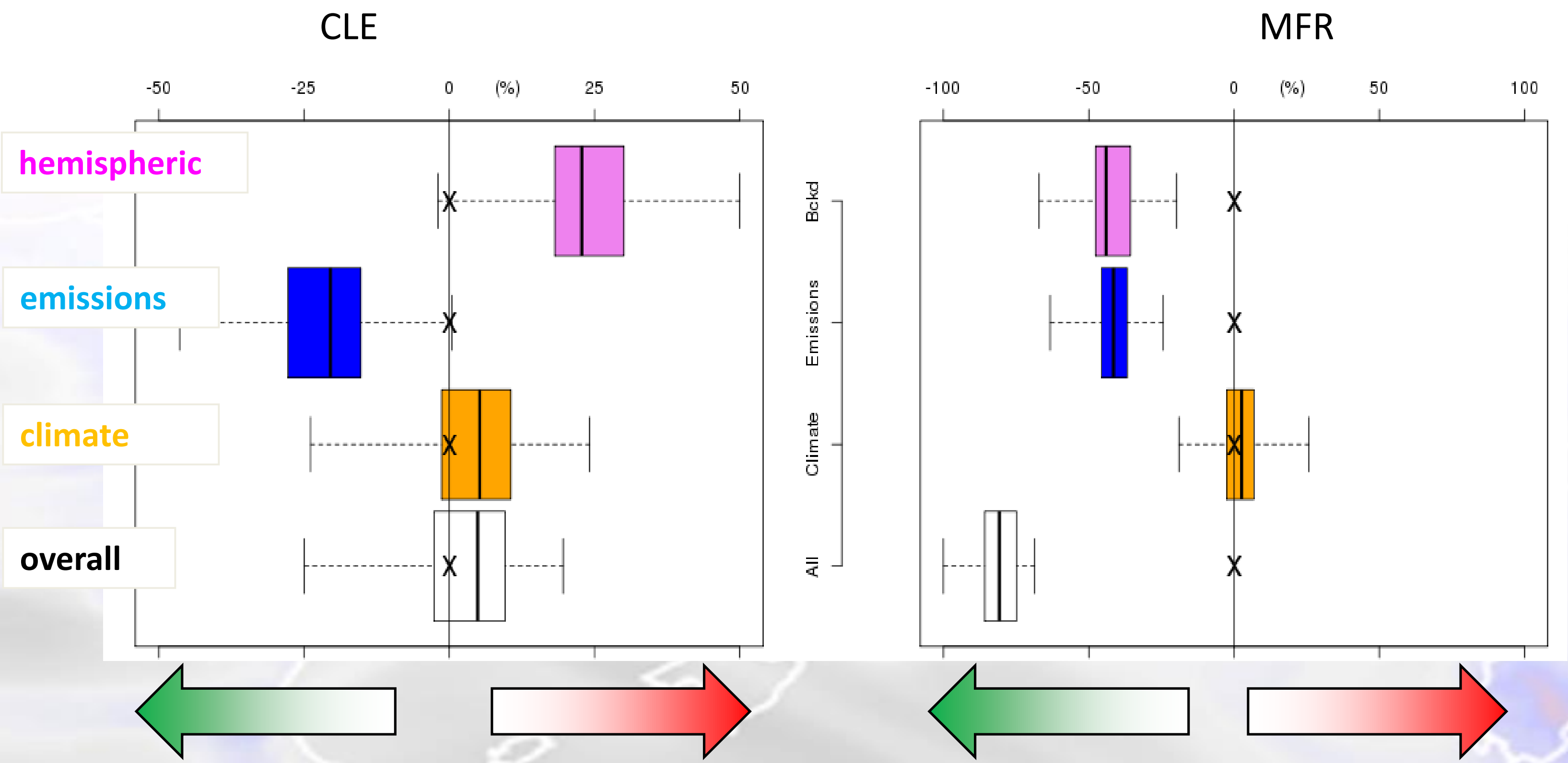
Future Evolution: non-climate factors

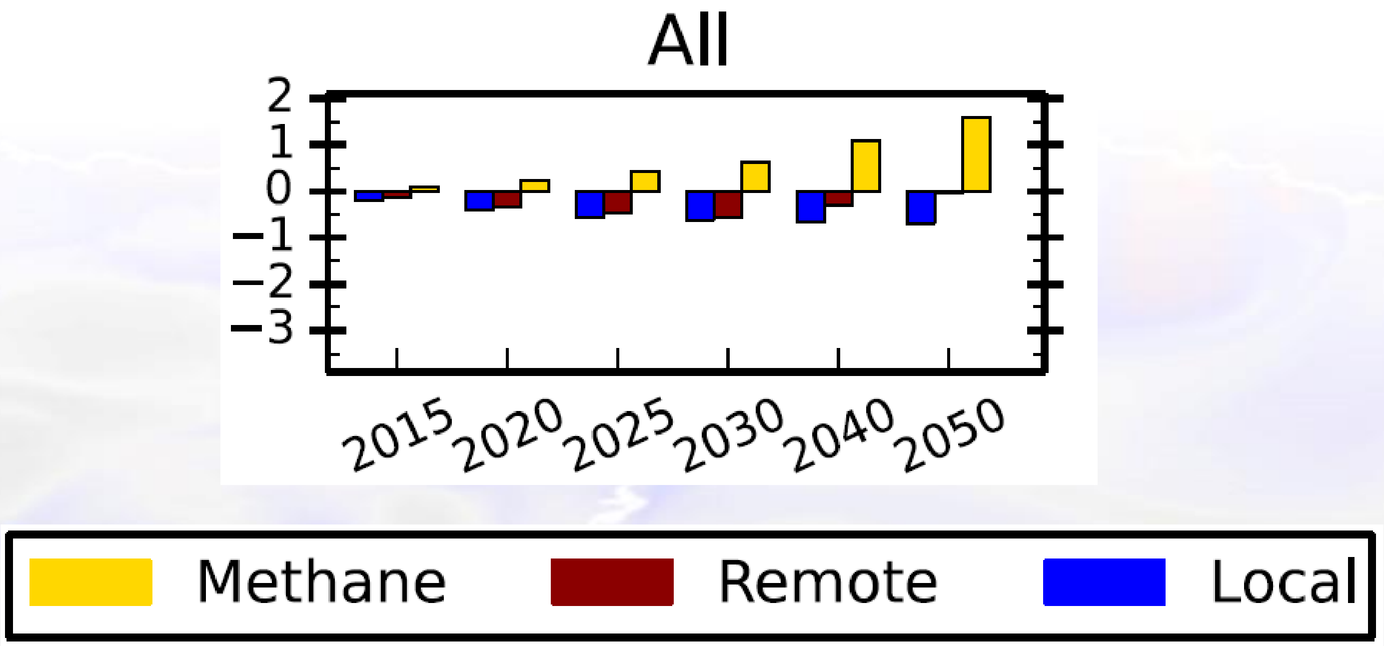
- Climate impact is significant but smaller than:
  - European Emissions
  - Hemispheric impact

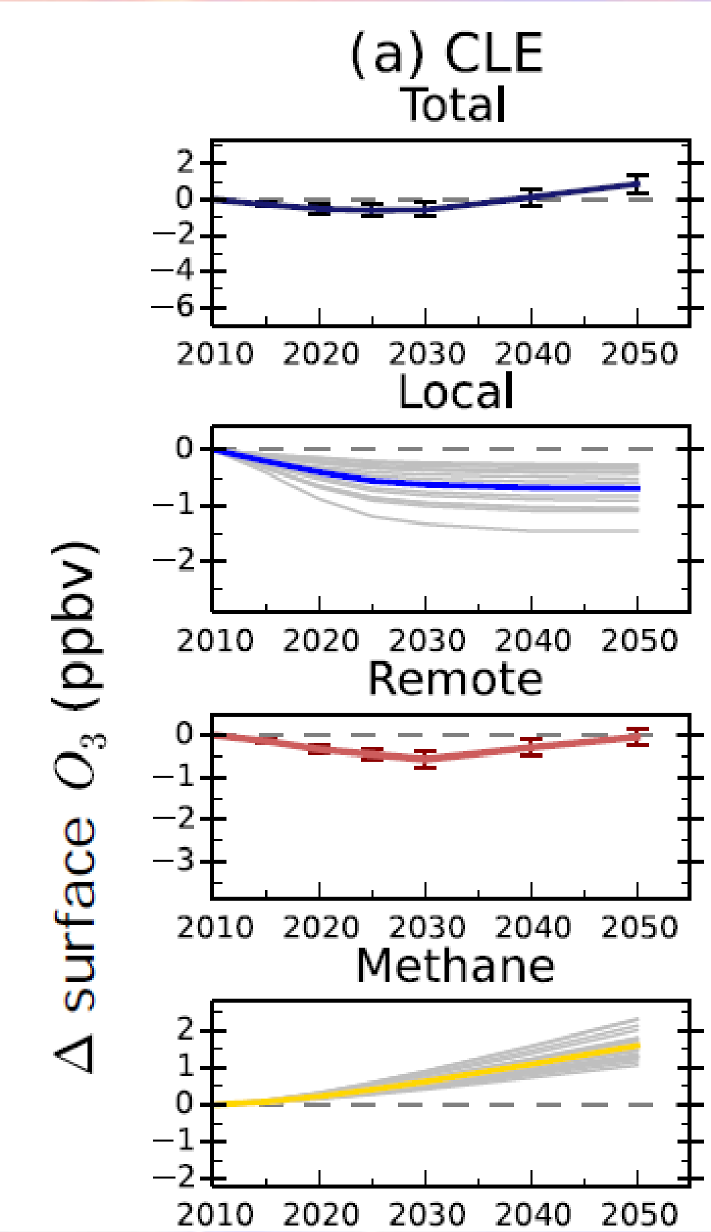


Colette et al, ACP 2013

HTAP

- On the long run, CH_4 will dominate the hemispheric impact (for ozone annual mean)





HTAP, Turnock et al., ACP 2018

Modelling challenge

- Derwent et al., 2014
  - The comparison found that no one model was the “best” model on all days, indicating that no single air quality model could currently be relied upon to inform policymakers robustly in terms of NOx versus VOC sensitivity.
  - For this reason, coupled with basic statistical arguments, it was argued that it is important to **maintain diversity in model approaches**

=> CAMS, Eurodelta, AQMEII, HTAP

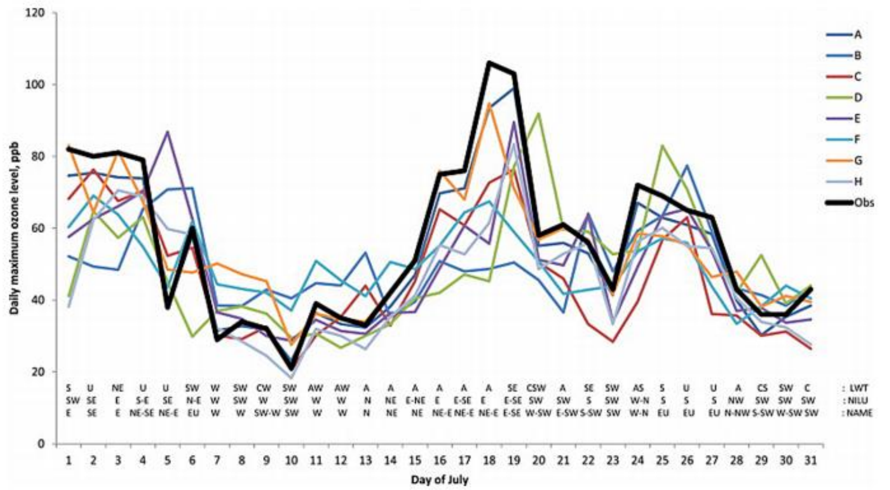


Figure 35. Daily maximum hourly ozone concentrations for eight models, A–H, in a comparison exercise against observations for July 2006 at Harwell, Oxfordshire, UK. Also shown are the daily advection regimes as Lamb weather types (LWT), NILU FLEXTRA trajectories (NILU) and NAME air history maps (NAME); see Derwent et al. (2014).

Conclusion

- After an increase in background ozone over the 20th century, the trends have stabilized since the late 1990s
- There are still different trends for various O3 metrics, with peaks (4MDA8) declining by 10% over 1990-2012
- For precursors (NOx&VOCs)
  - Relative agreement emissions & background concentrations (decrease 30 to 40%)
- Model attribution & statistical data mining do not show that the discrepancy between precursor (30-40%) and 4MDA8 trends (10%) would be due to any compensating factor
  - => non-linear chemistry remains the main suspect
- The limited magnitude of recents trends is a concern when put in perspective with
  - Future climate penalty
  - Hemispheric impact (CH4)

- Knowledge gaps
  - Lacking European assessment of proximity sites (e.g. NO&NO2 at trafic sites)
  - VOC speciation
  - Difficult to compare various sources because of metric sensitivity (esp: global/regional approaches)
  - Temporal records are still too short
    - Scarce network before 2000 (geographical representativity)
    - 10-12yr is too short to detect significant O3 trends