Global projections of ground-level ozone in 2050

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Bullet points for report

- Future global surface O_3 strongly influenced by:
  - Emissions (probably largest uncertainty?)
    - NO_x and CH_4 crucial (VOCs & CO less so?)
    - Surface O_3 has roughly doubled since pre-industrial
  - Climate change - in general:
    - Negative feedback over the tropical oceans (water vapour)
    - (Positive feedback from enhanced strat-trop exchange)
    - Positive feedback over land, particularly polluted areas (mechanisms not yet clear - temperature: PAN $\rightarrow$ NO_x; biogenic VOC; water vapour; lightning NO_x has a variable impact)
  - For the 2050 scenario considered here, improvements in O_3 from emissions controls may be largely reversed or even overturned by climate impacts
  - Possible impacts from land use change (e.g. biomass burning) and stratospheric change not seriously addressed yet

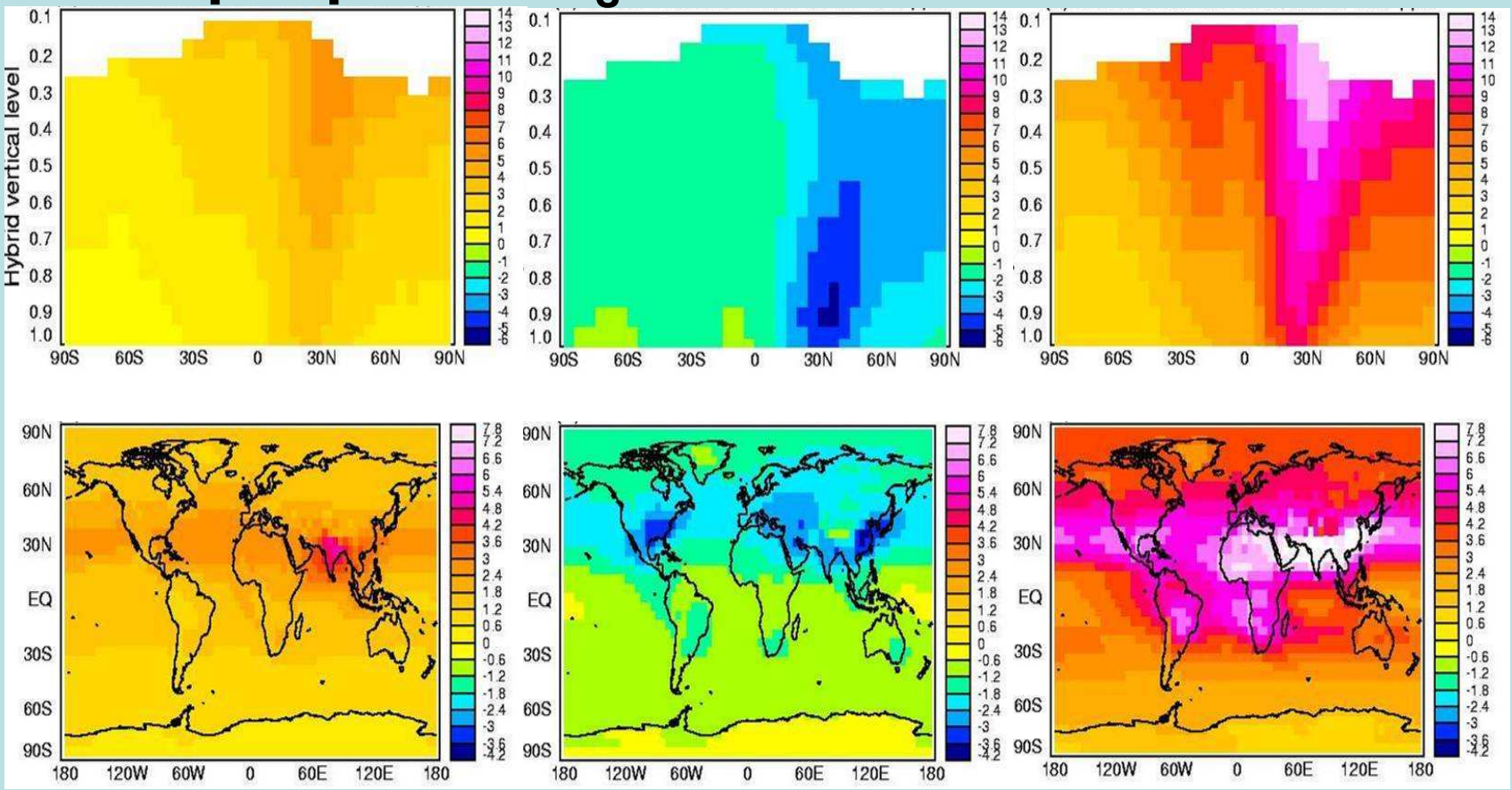
ACCENT inter-comparison

- Focus on 2030 – of direct interest to policymakers
- Go beyond radiative forcing: also consider ozone AQ, N- and S-deposition, and the use of satellite data to evaluate models
- Present-day base case for evaluation:
  - S1: 2000
- Consider three 2030 emissions scenar
  - S2: 2030 IIASA CLE ('central')
  - S3: 2030 IIASA MFR ('optimistic')
  - S4: 2030 SRES A2 ('pessimistic')
- Also consider the effect of climate cha
  - S5: 2030 CLE + imposed 2030 climate

Future changes in composition related to emissions

Future changes in composition related to climate change 5-10 year runs

Multi-model ensemble mean change in tropospheric O_3 2000-2030 under 3 scenarios



Annual Zonal Mean ΔO_3 / ppbv

Annual Tropo-spheric Column ΔO_3 / DU

'Central'

IIASA CLE
SRES B2 economy +
Current AQ Legislation

'Optimistic'

IIASA MFR
SRES B2 economy +
Maximum Feasible Reductions

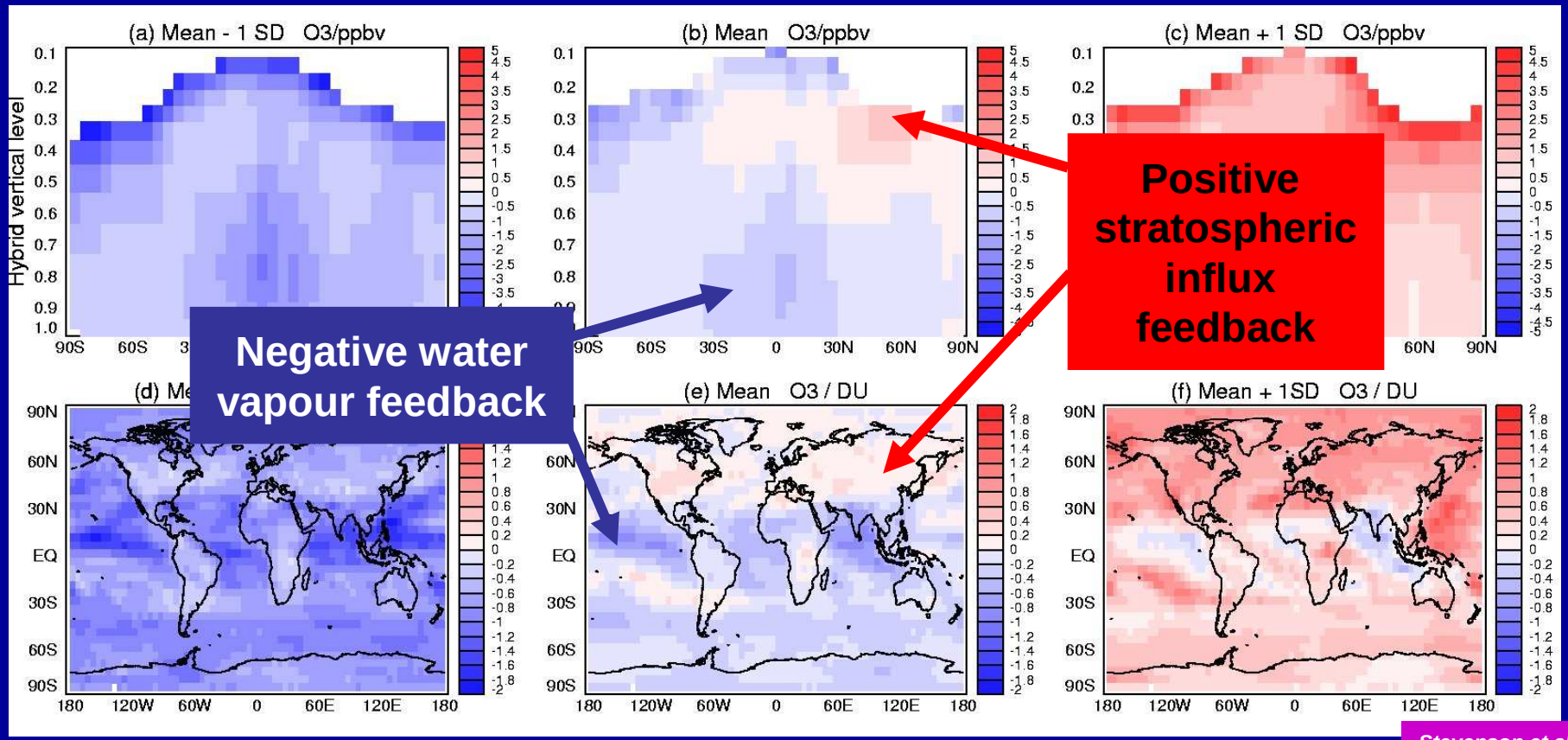
'Pessimistic'

IPCC SRES A2
High economic growth +
Little AQ legislation

Stevenson et al., 2006 JGR

Quantitative assessment of future O_3 for 3 scenarios – allows economic and environmental costing of policy options

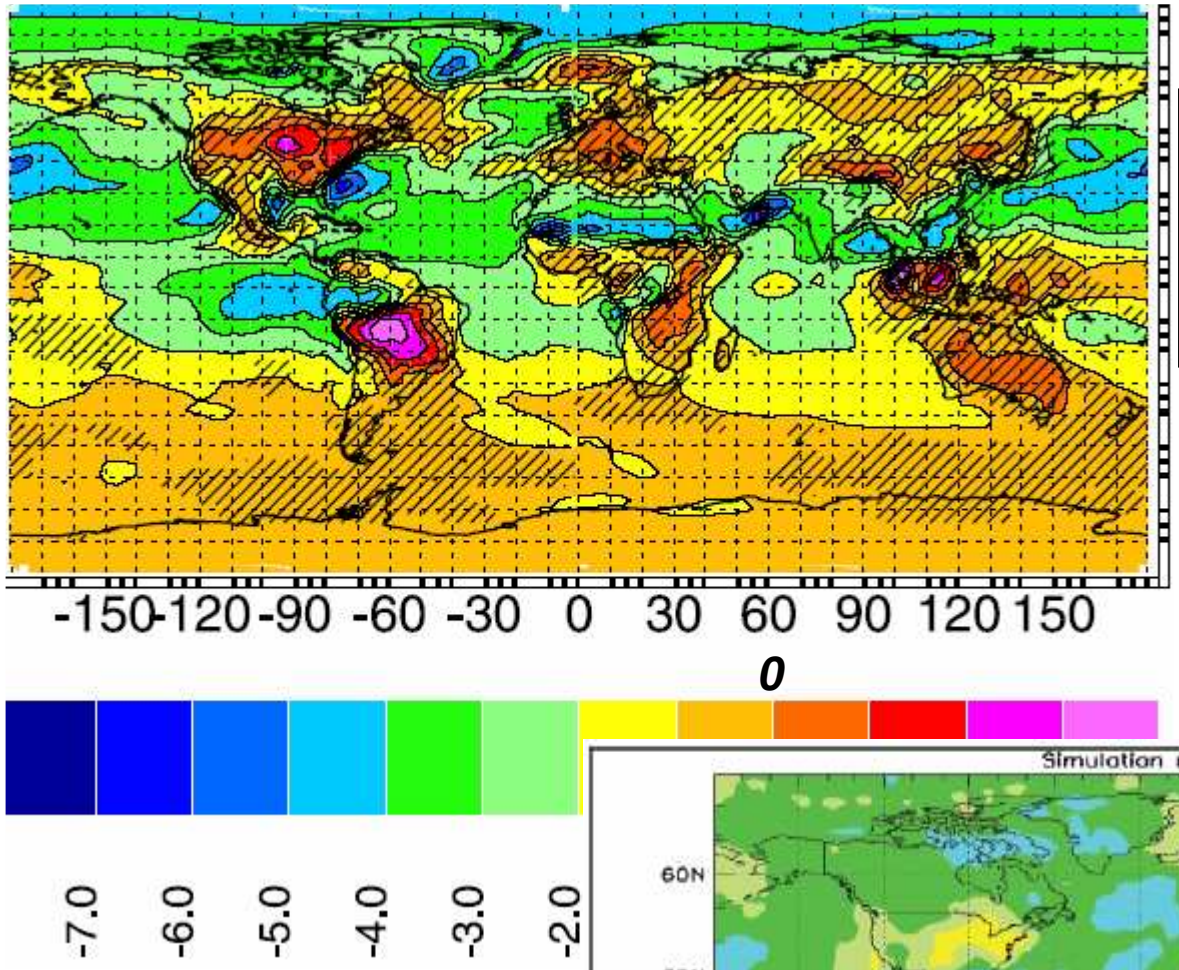
Impact of Climate Change on Ozone by 2030 (ensemble of 10 models)



Stevenson et al., 2006 JGR

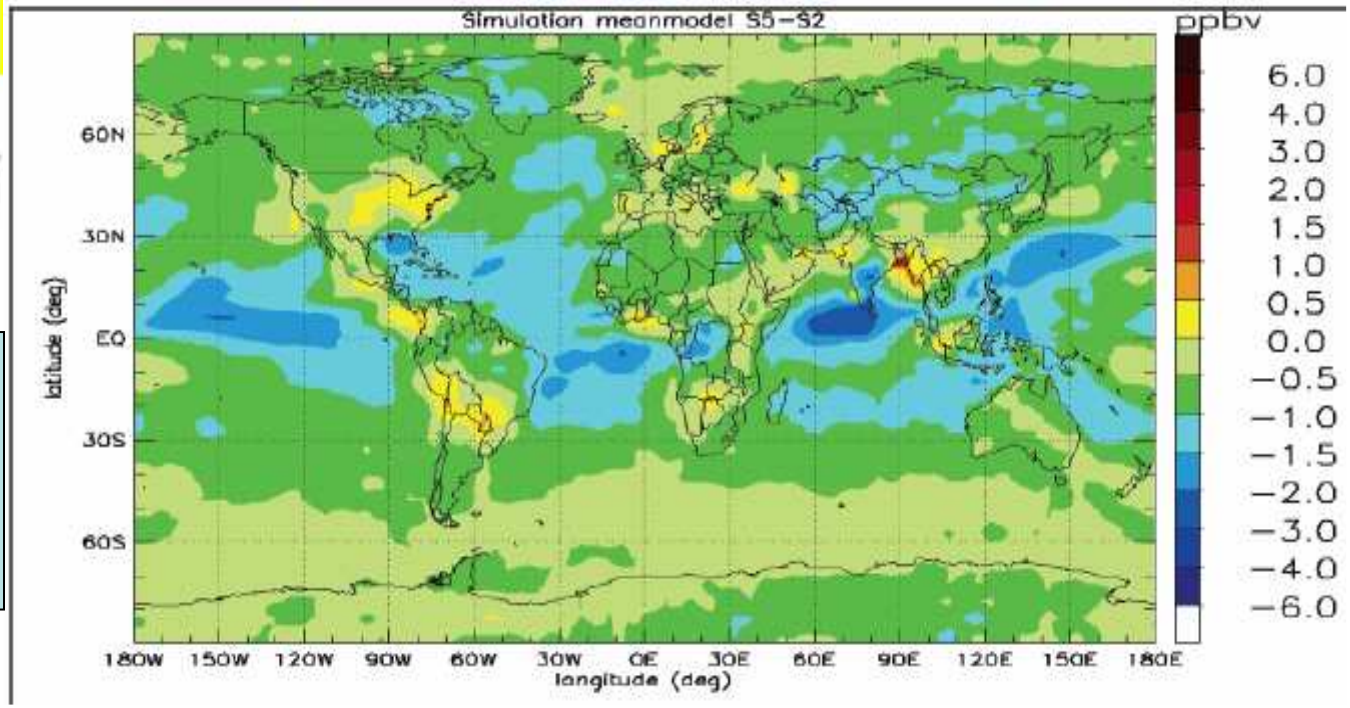
Mean - 1SD **Mean** **Mean + 1SD**

Positive and negative feedbacks – no clear consensus



Murazaki & Hess, 2006
MOZART+
NCAR CSM1.0
SRES A1 2090s v 1990s

Impact of climate change on surface O_3

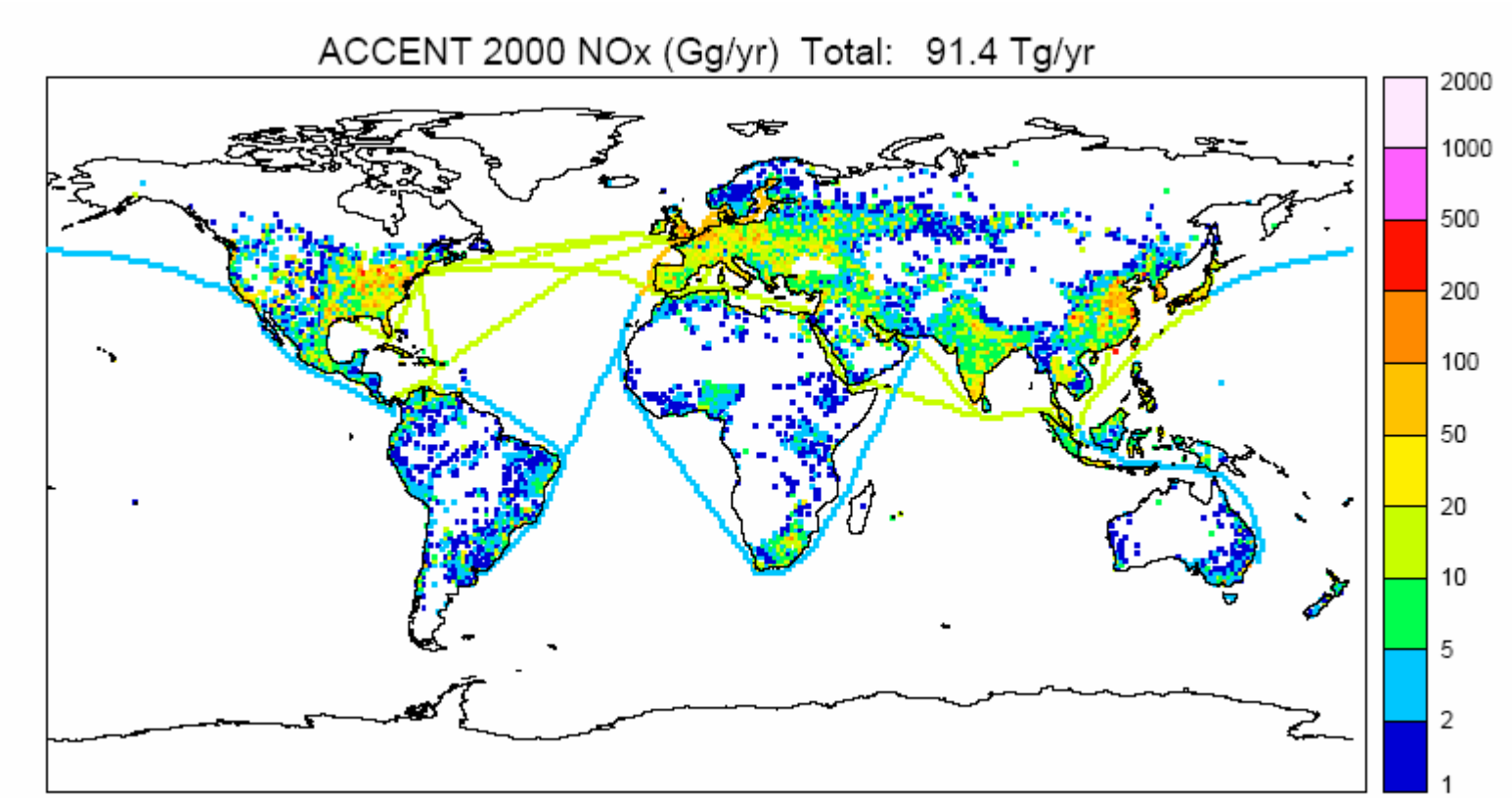


Dentener et al., 2006
10 models
Various 2030 scenarios

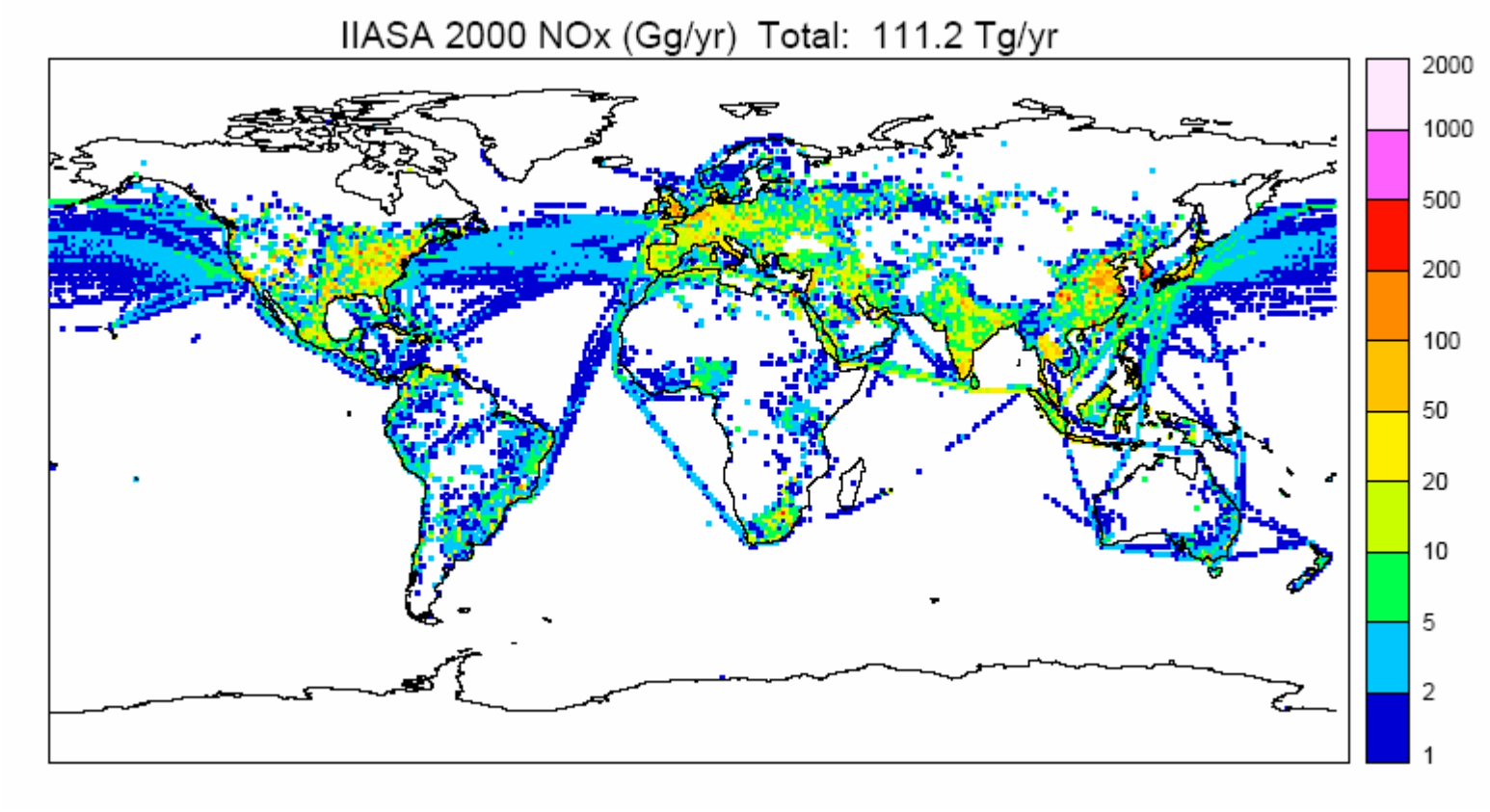
New 2000 and 2050 emissions

- New emissions (NO_x & CO) totals and 2050 projections for 11 world regions from IIASA (Rafaj & Amann)
- New ship emissions (Corbett & Eyring)
- Use ACCENT 2000 distribution as base
- Scale 2000 & 2050 fields; replace ships
- Assume VOCs follow CO
- Use IPCC SRES CH_4 concentrations

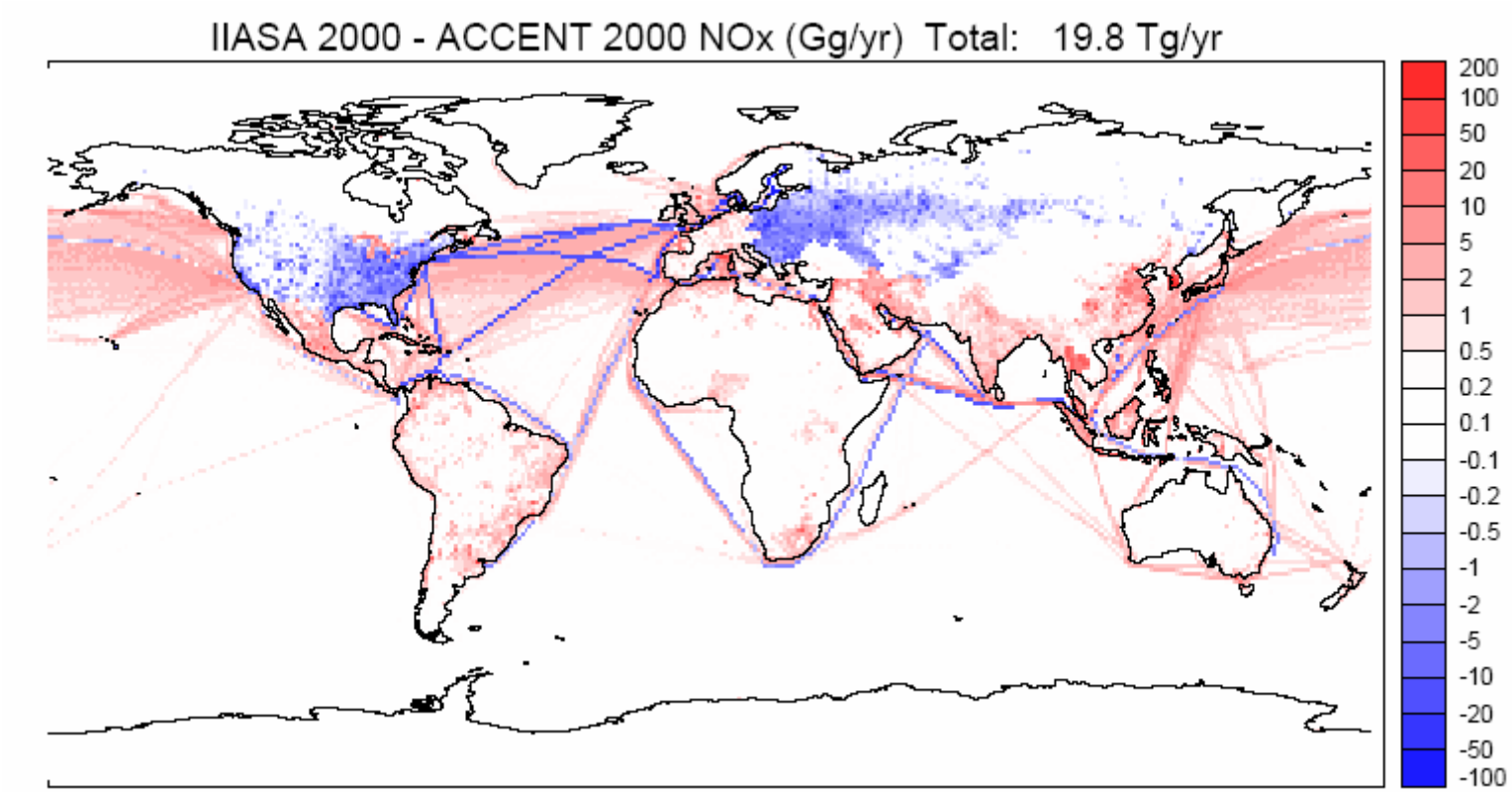
ACCENT 2000 NOx



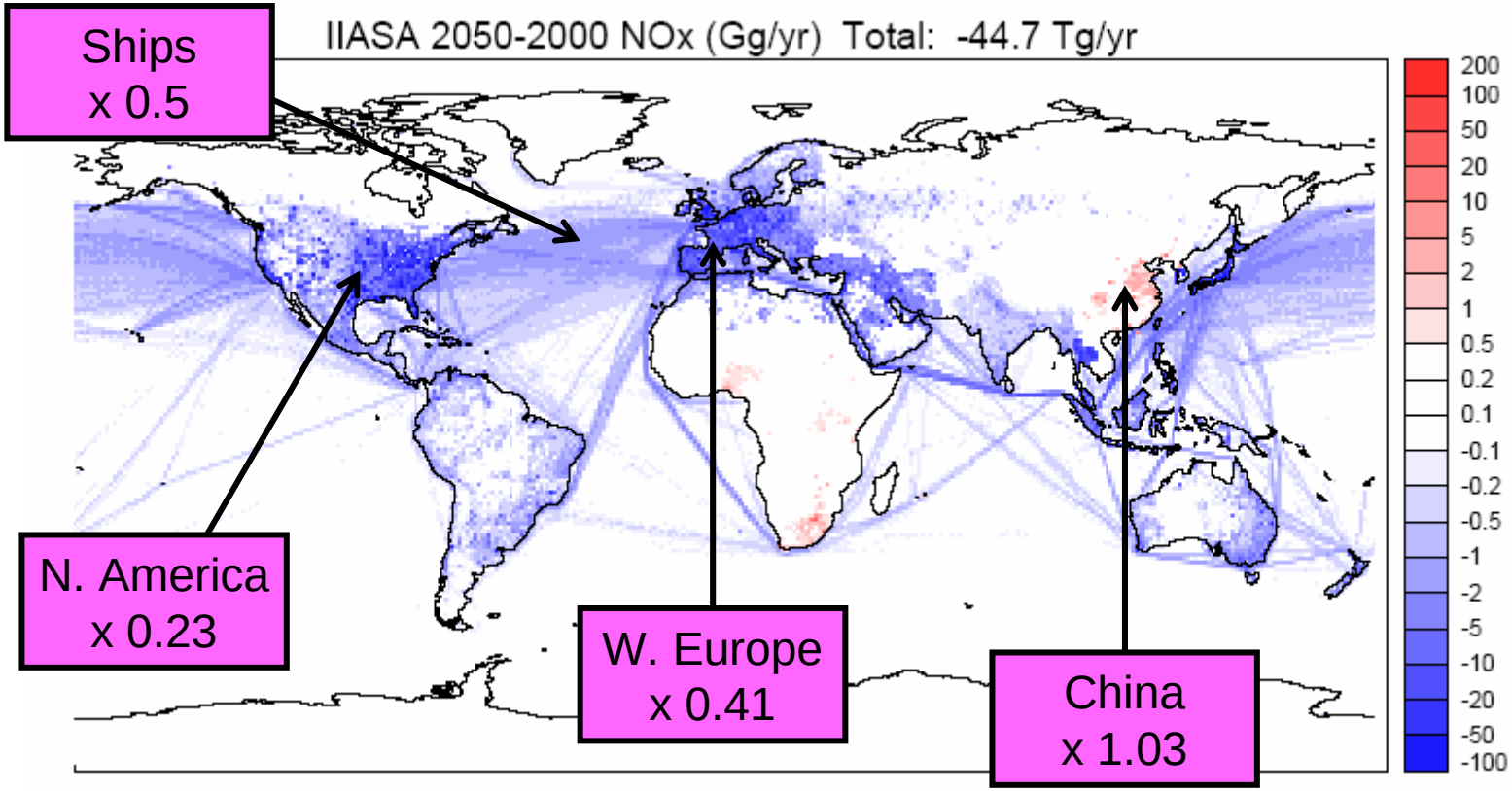
New IIASA 2000 NOx



Difference in NOx emissions: IIASA 2000 – ACCENT 2000



NOx emissions 2050-2000



Reduce almost everywhere – global total down ~40%

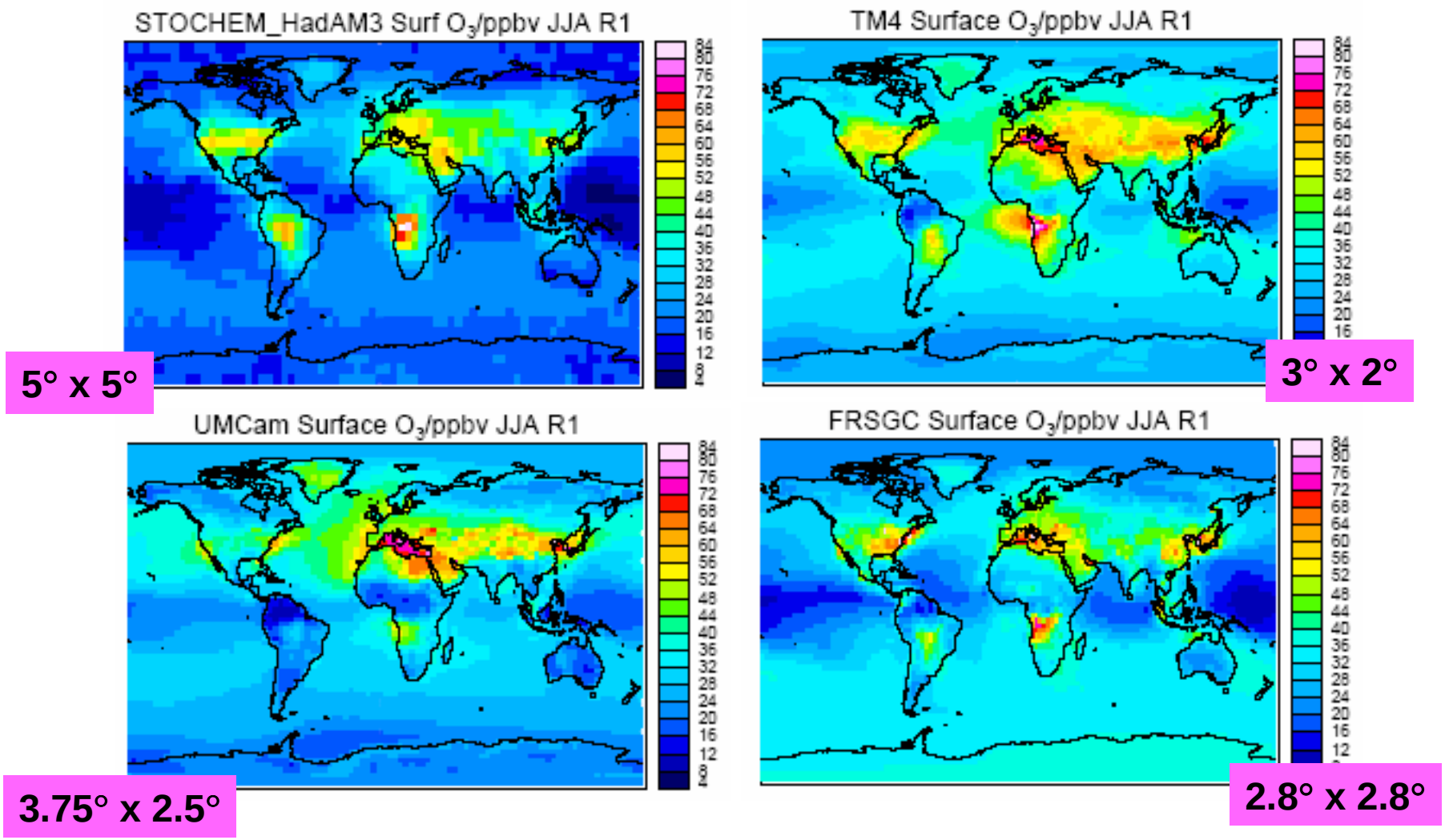
Simulations

	Emissions	Climate	CH_4/ppbv	Run length/yrs
R1	2000	1990s	1760	5+
R2	2050	1990s	2363 (B2)	5+
R3	2050	2050s	2363 (B2)	5+
R4	1750 (P-I)	1990s	700 (P-I)	1
R5	2050	2050s	1760	1

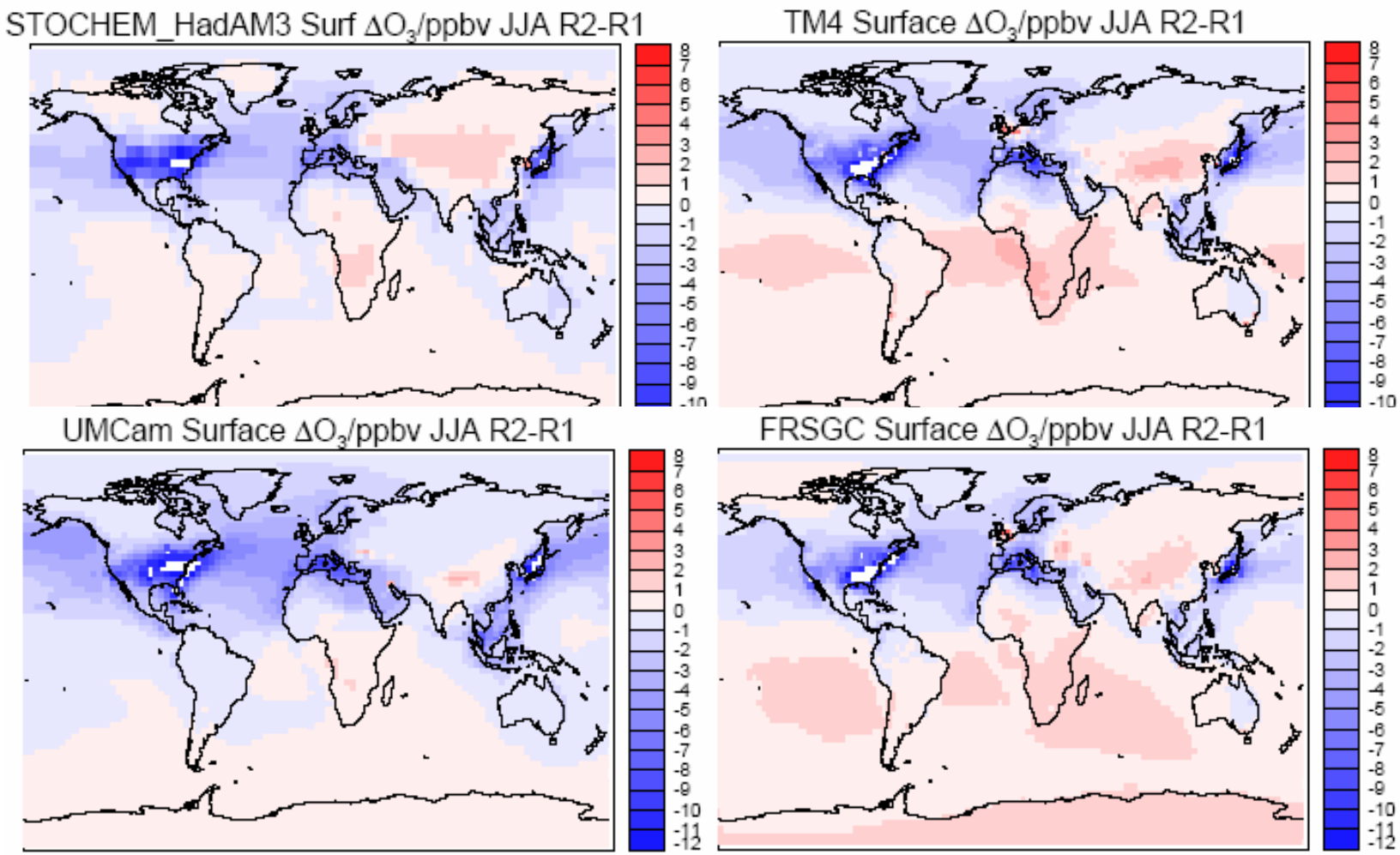
Participating groups

- University of Edinburgh
  - STOCHEM_HadAM3 (R1, R2, R3)
- University of Cambridge
  - UMCam (R1, R2, R3, R5)
  - FRSGC/UCI (R1, R2, R4, R5)
- KNMI
  - TM4 (R1, R2, R4, R5)
- Met. Office
  - STOCHEM_HadGEM (R1, R2, R3)
- University L'Aquila
  - ULAQ – low res model (R1, R2, R3, R4, R5)

Year 2000 (R1) Jun-Jul-Aug (JJA)

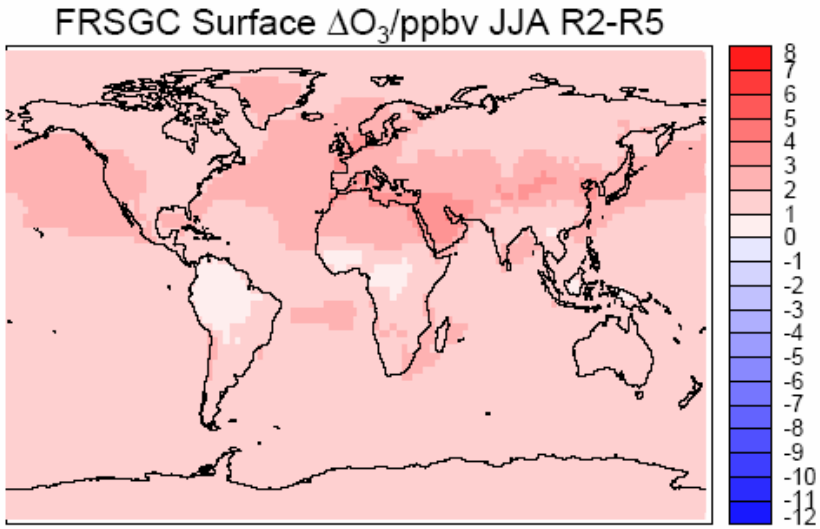


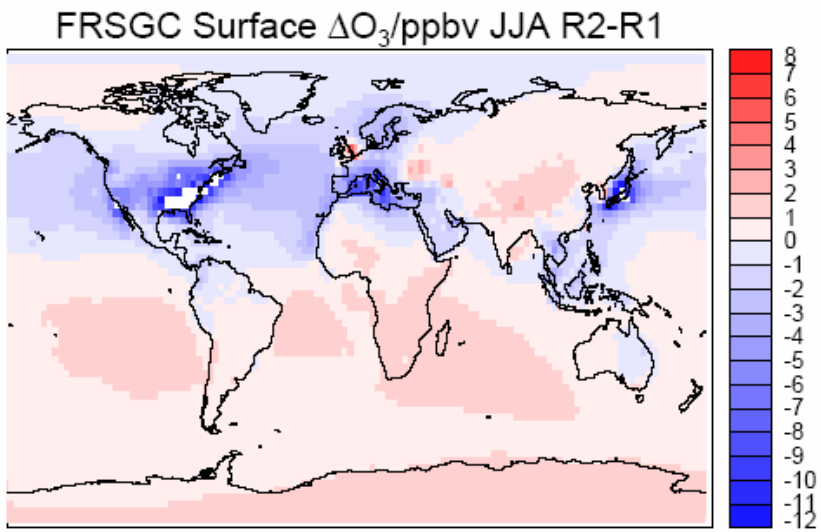
2050-2000 emissions only (R2-R1) JJA

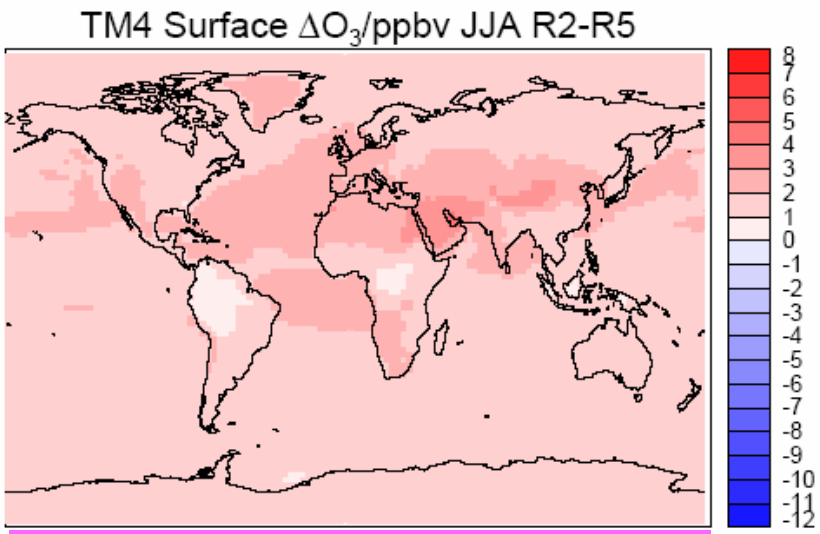


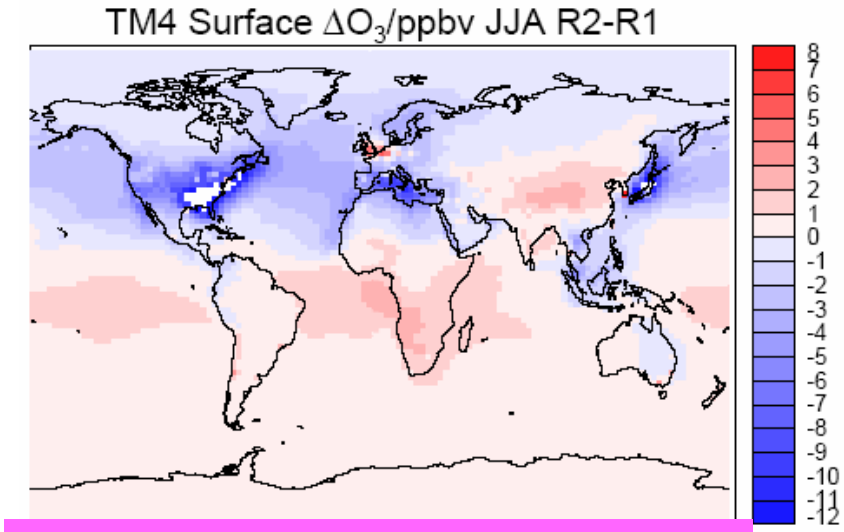
NO_x emissions reductions vs CH_4 increase

Contribution of CH_4 to 2050 changes





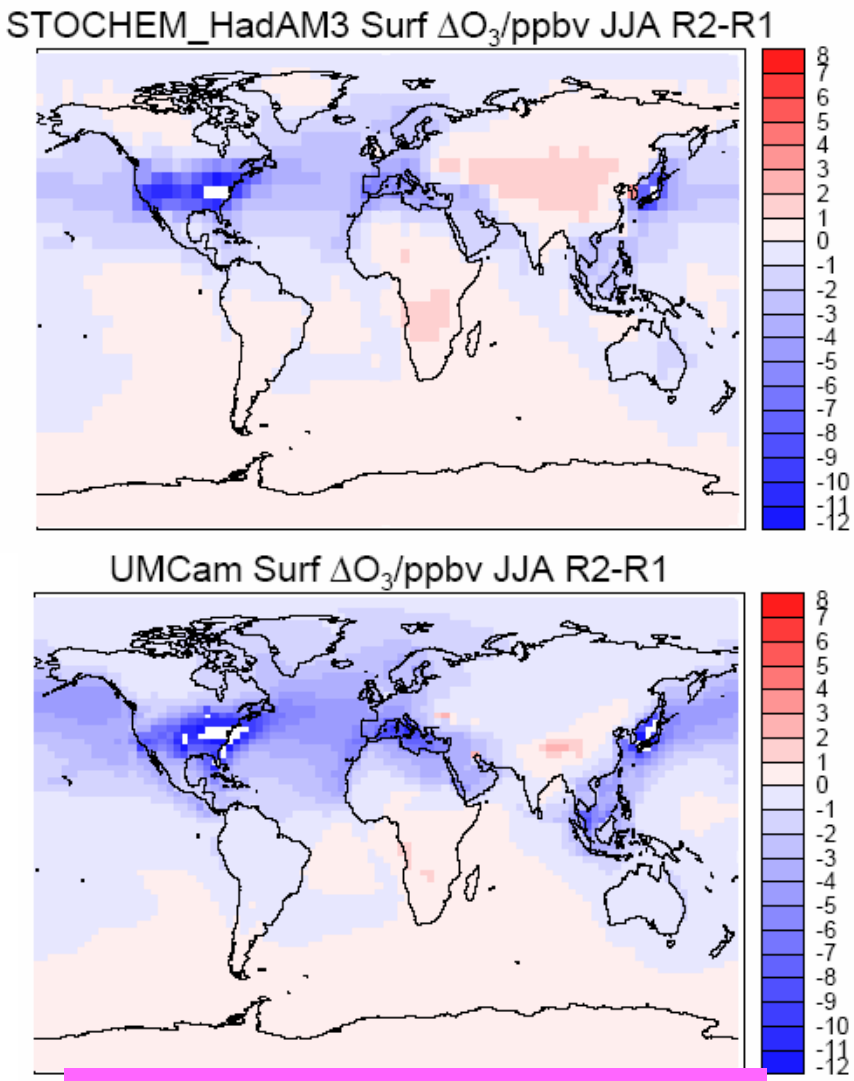




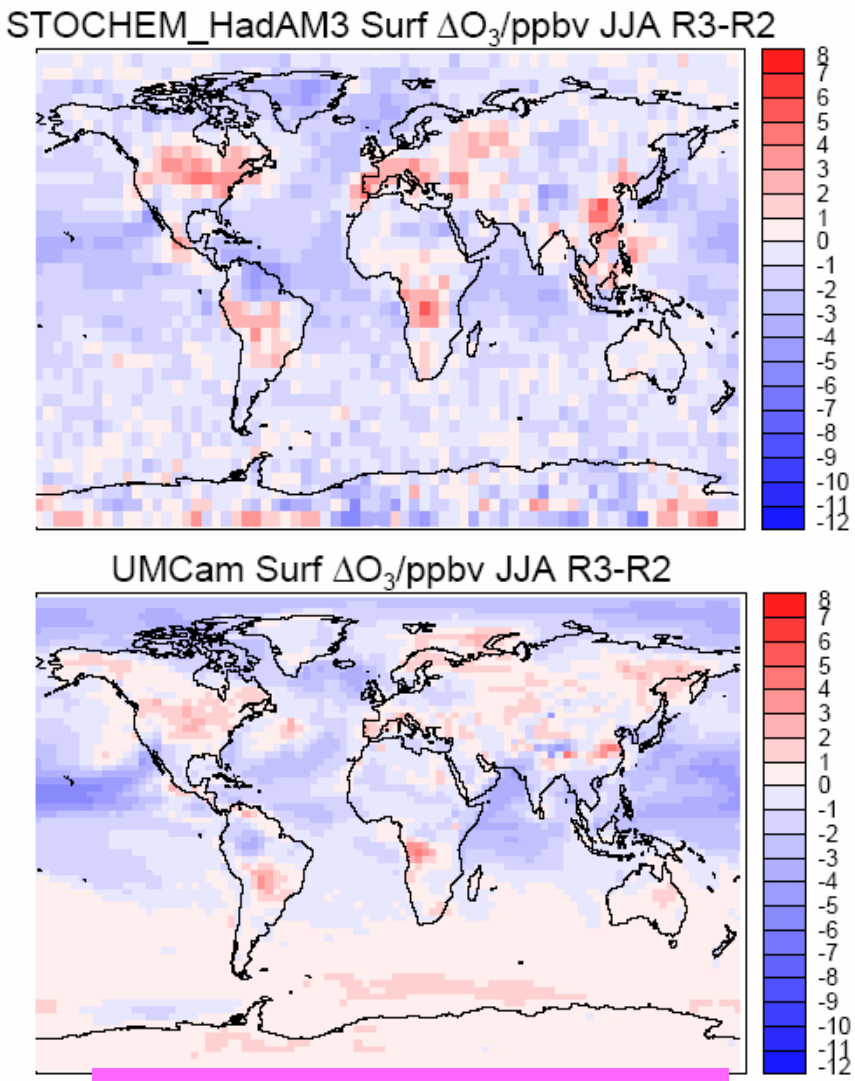
CH_4: 1760 → 2363 ppbv
⇒ O_3 up globally by 1-4 ppbv

NO_x emiss: -40%
⇒ O_3 down locally by >10 ppbv

Change in JJA O_3 2050-2000 due to changes in emissions / climate

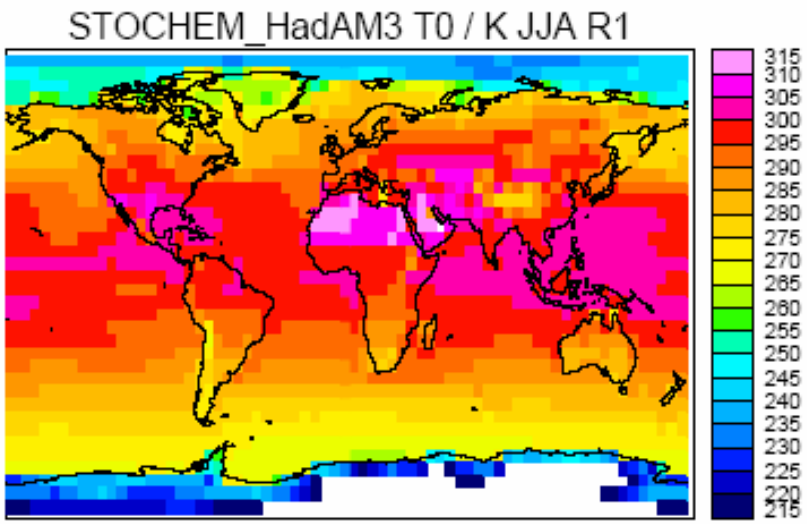


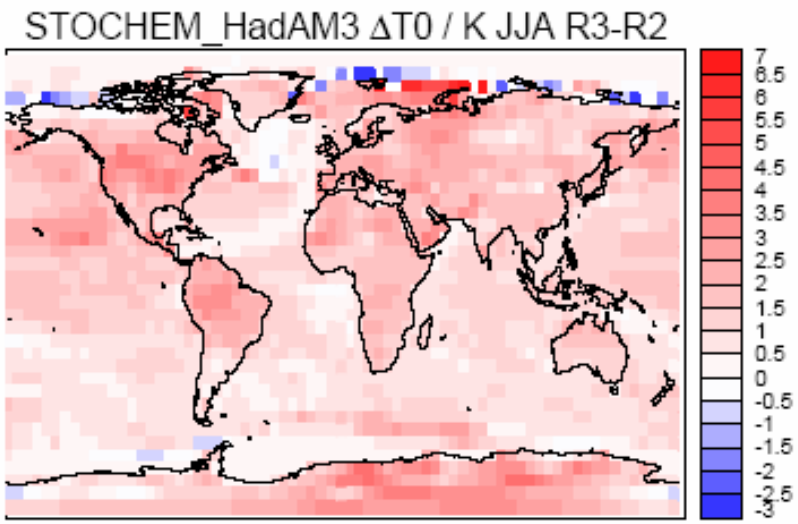
Emissions change 2000-2050

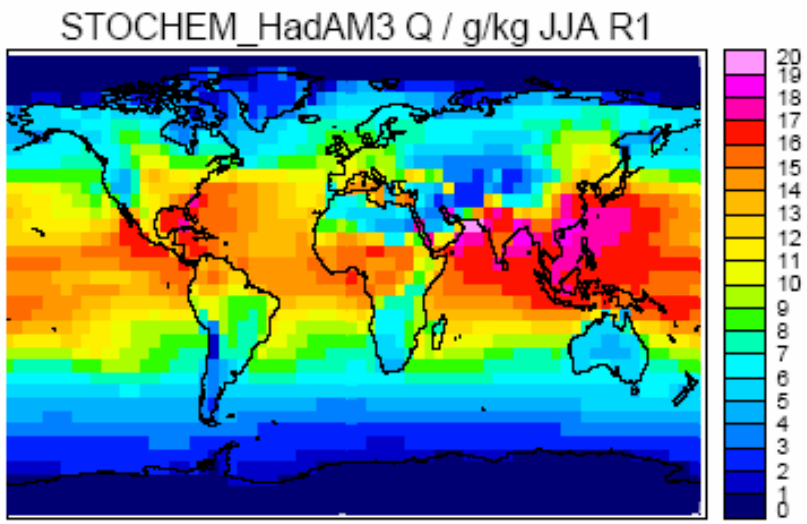


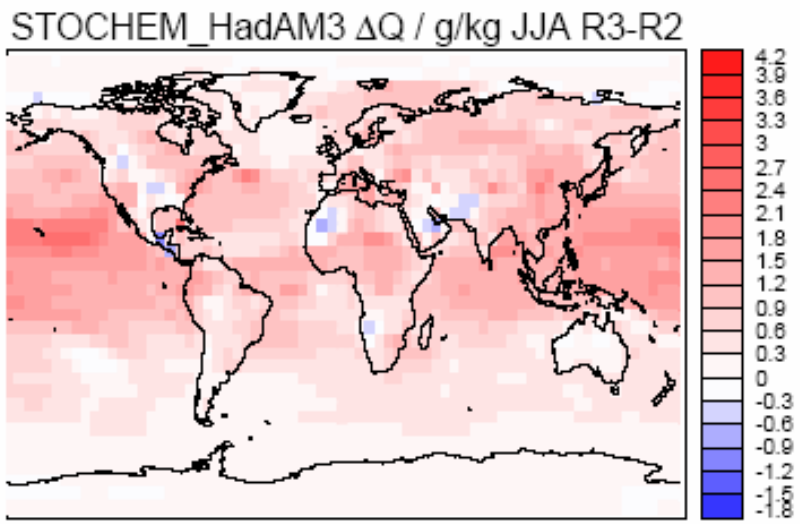
Climate change 2000-2050

Y2000 T0 & Q / Changes 2050-2000

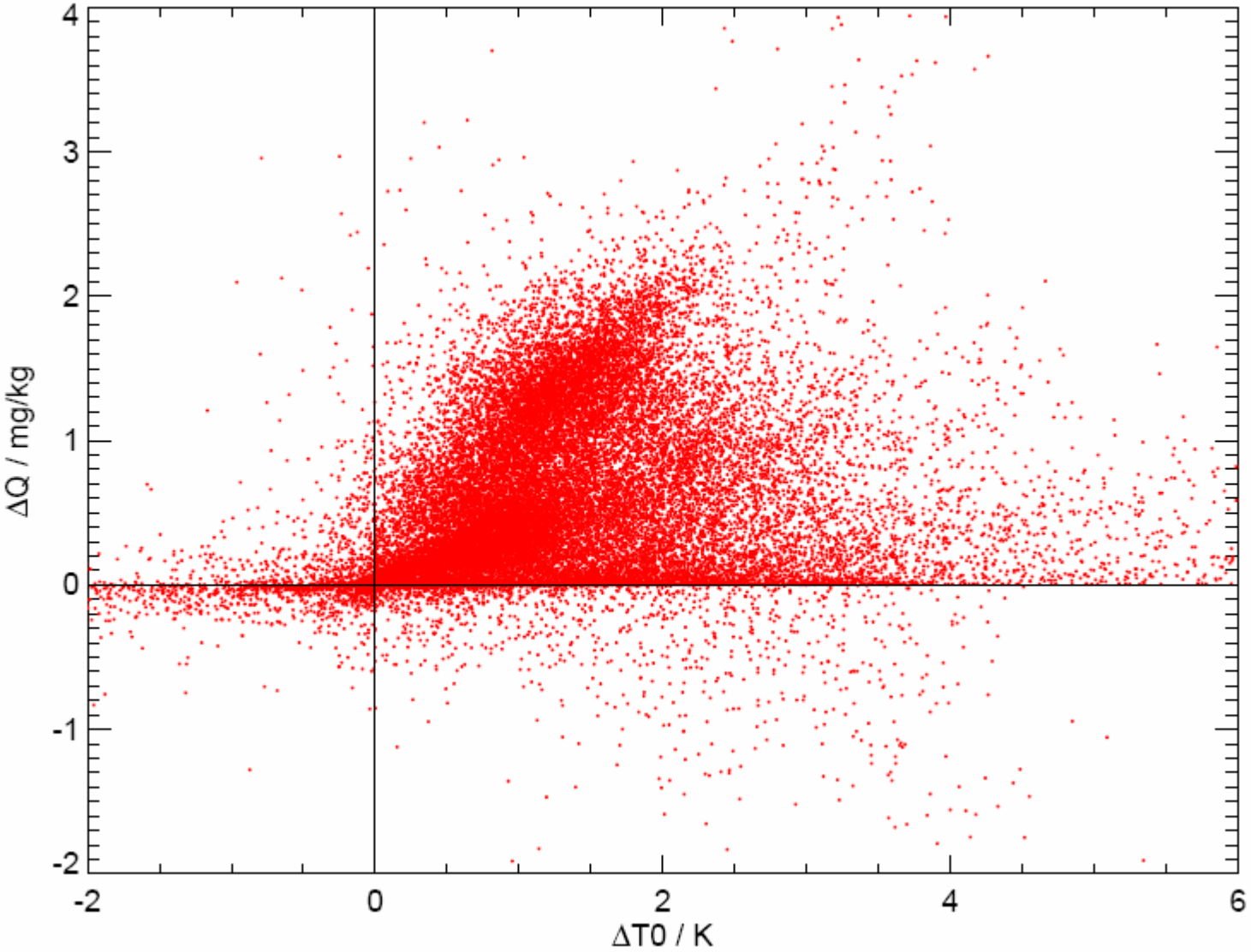




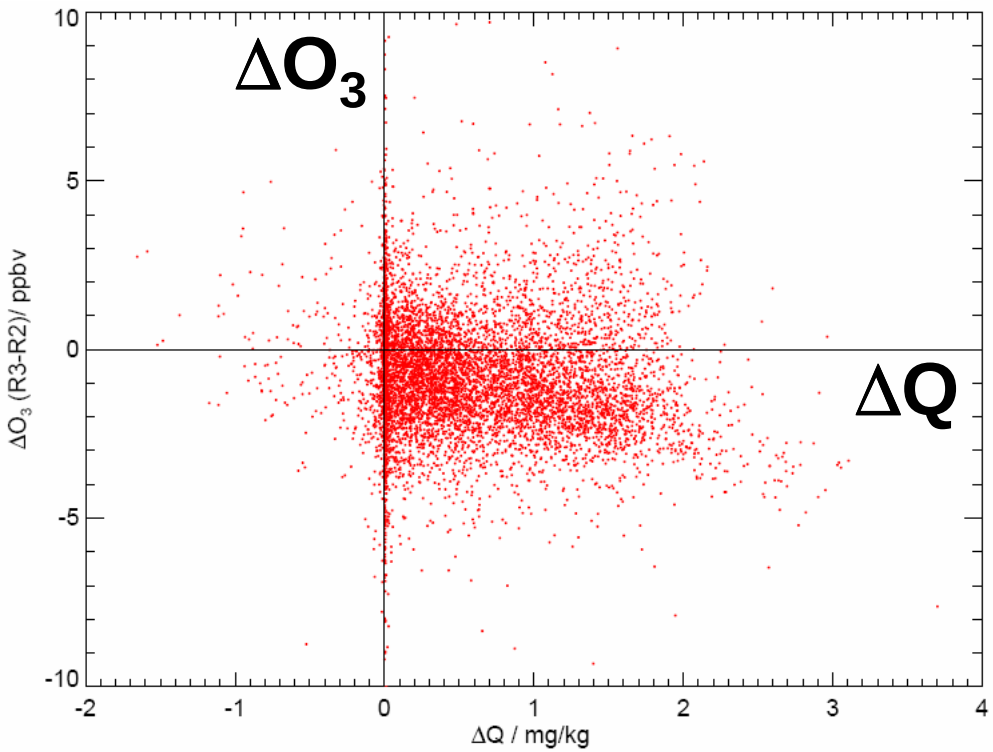


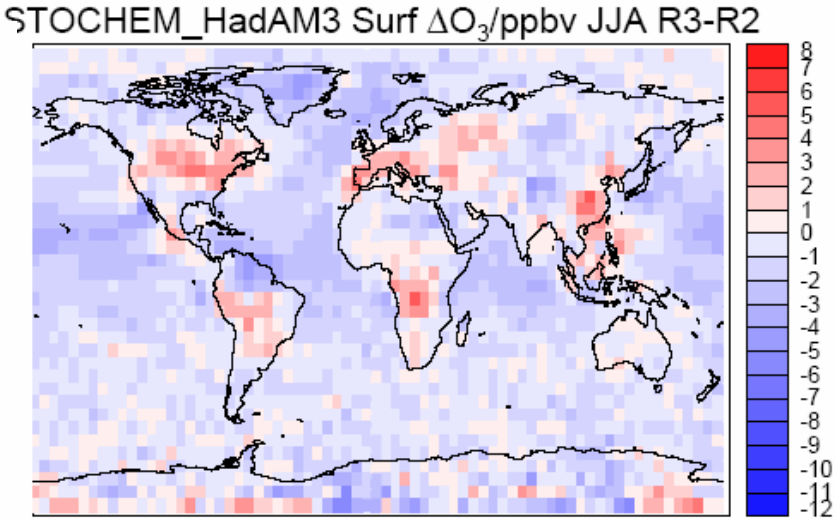


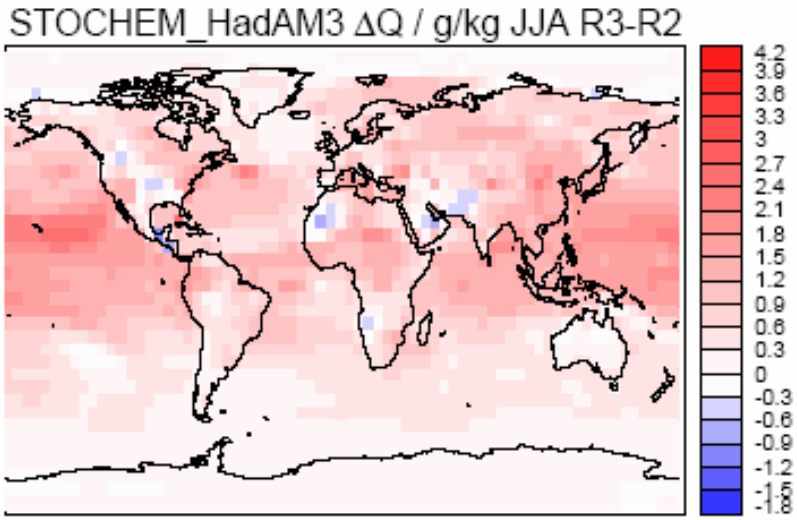
ΔQ related to ΔT0



ΔQ dominates ΔO_3 over tropical oceans







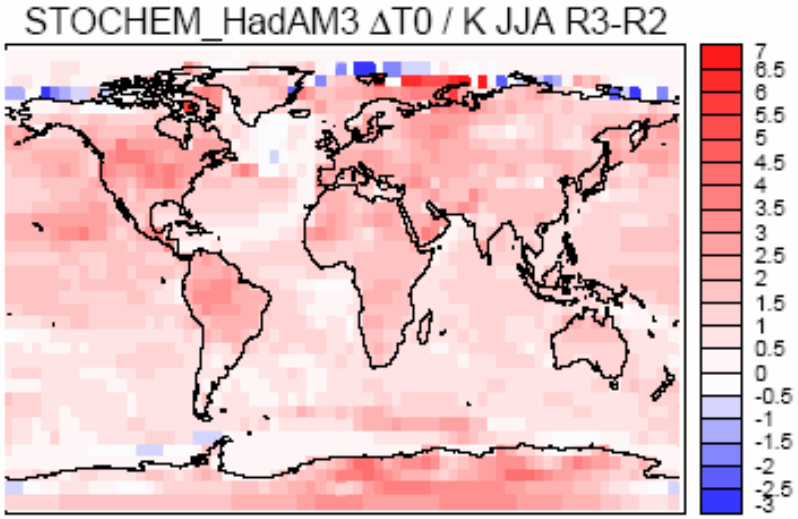
Increased humidity promotes O_3 destruction via:

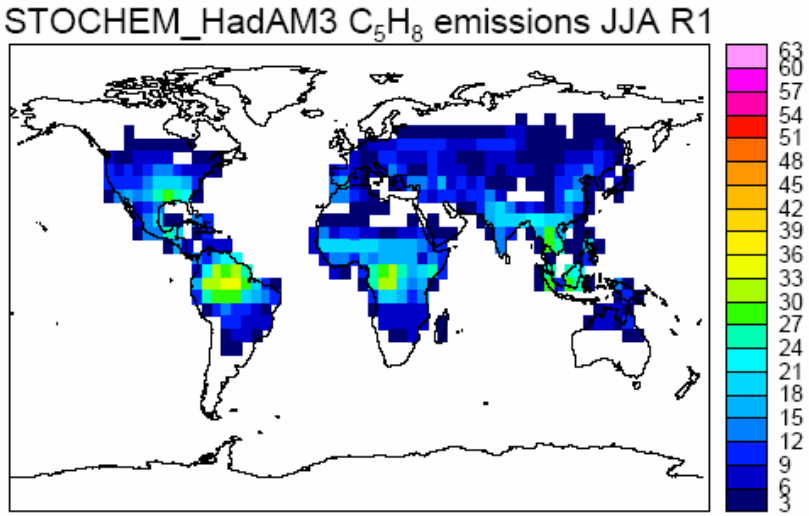
$$O(^1D) + H_2O \rightarrow 2OH$$

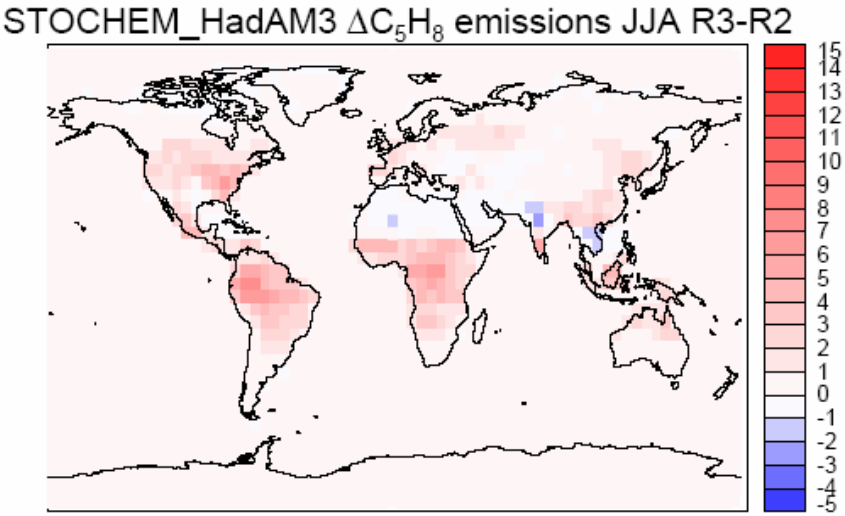
(Use land-sea mask on data)

T0 and isoprene emissions

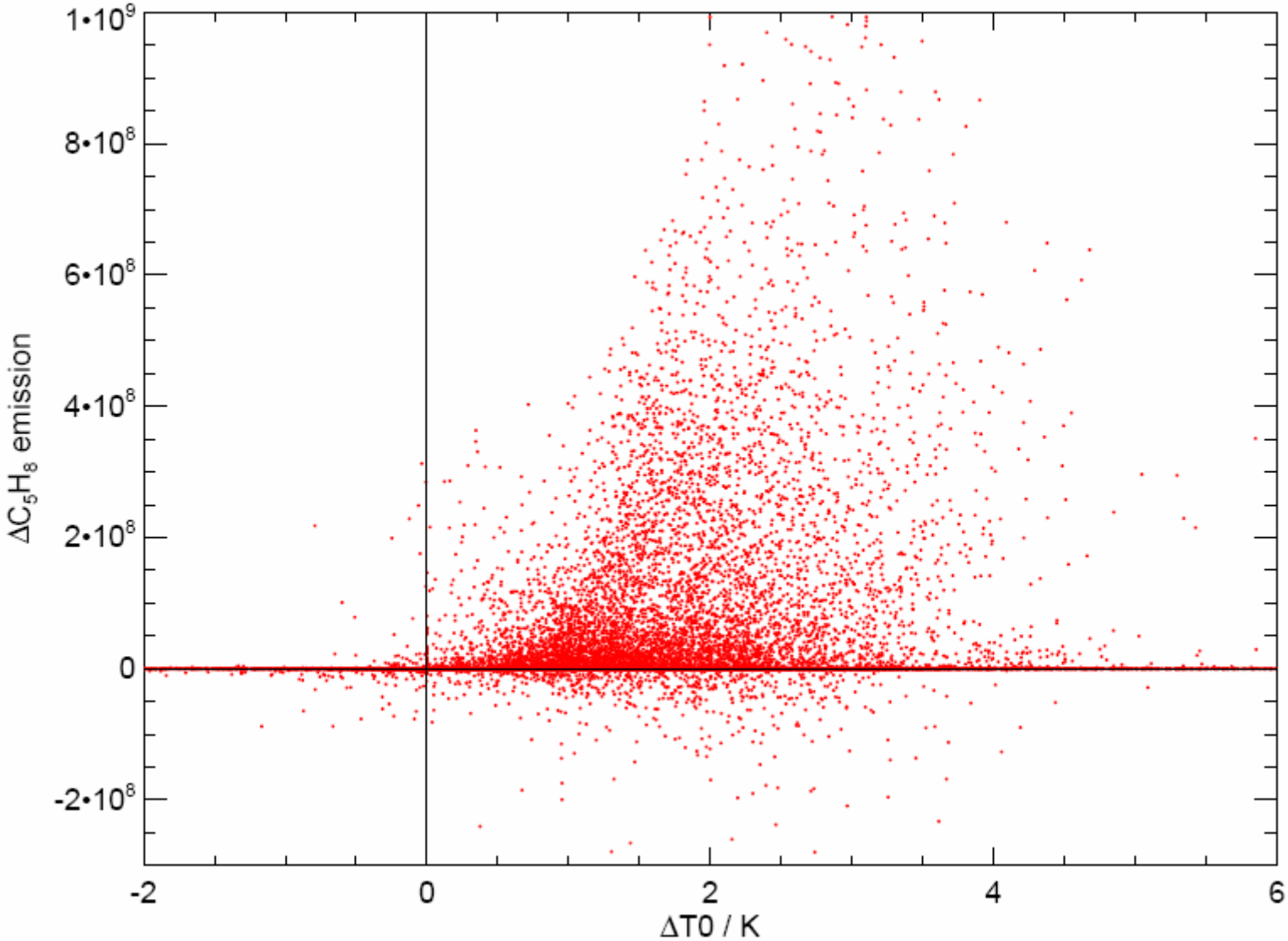
STOCHEM includes the Guenther et al. (1995) algorithm relating isoprene emissions to temperature and PAR.



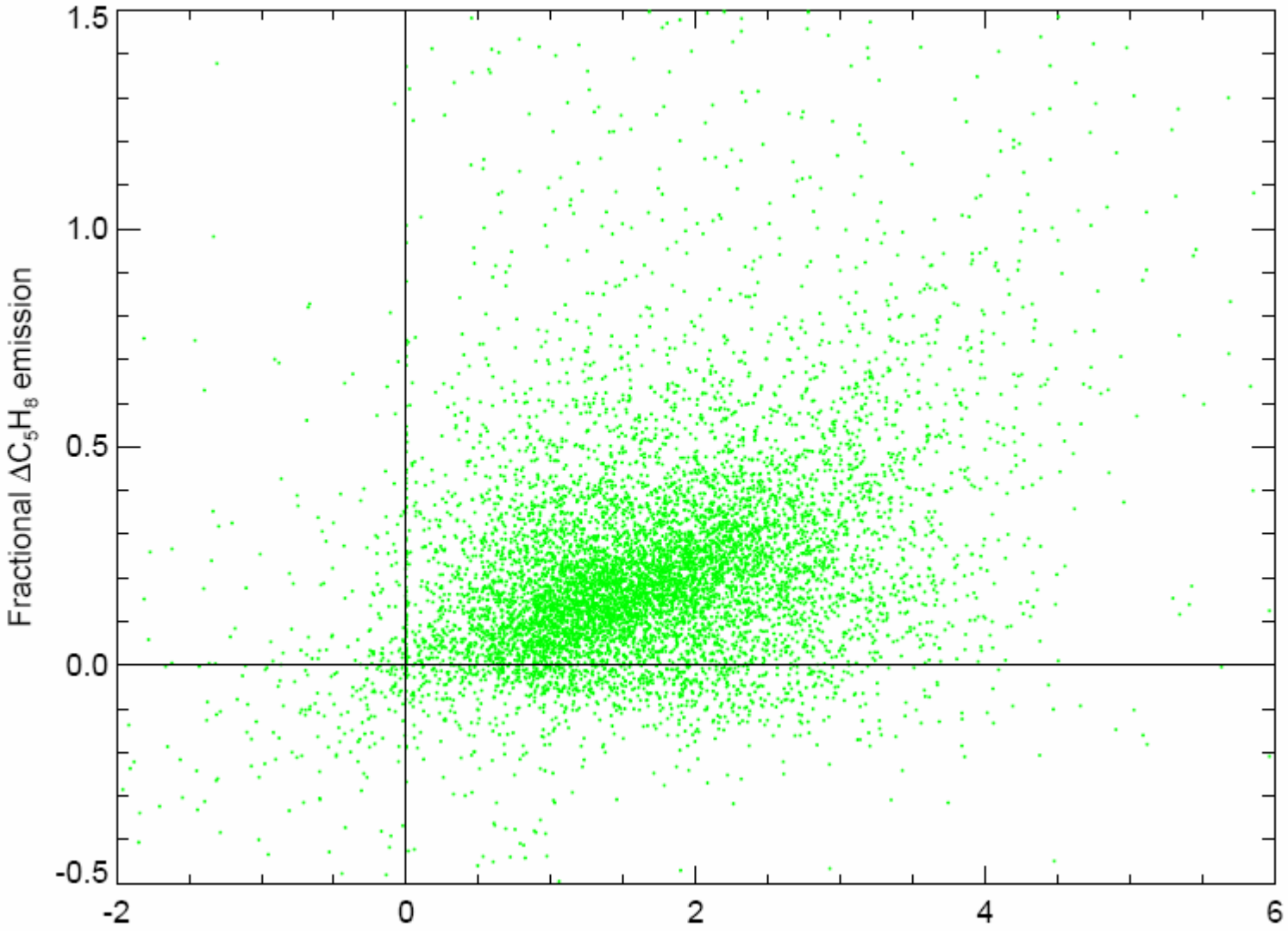




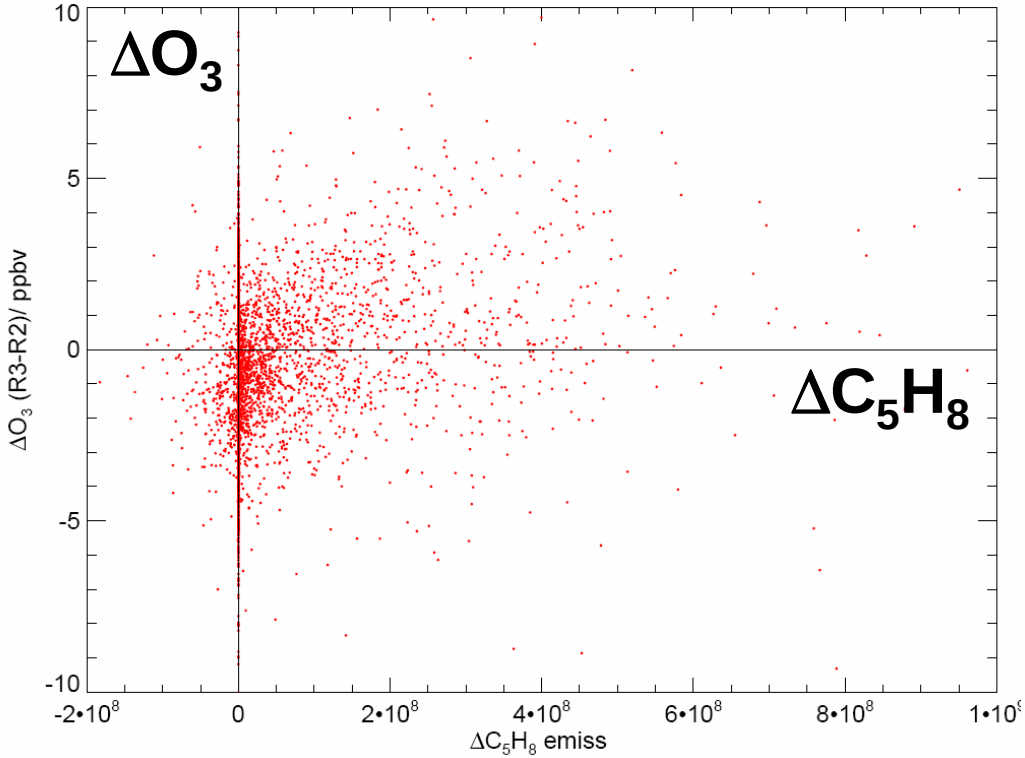
ΔC_5H_8 emissions related to $\Delta T0$

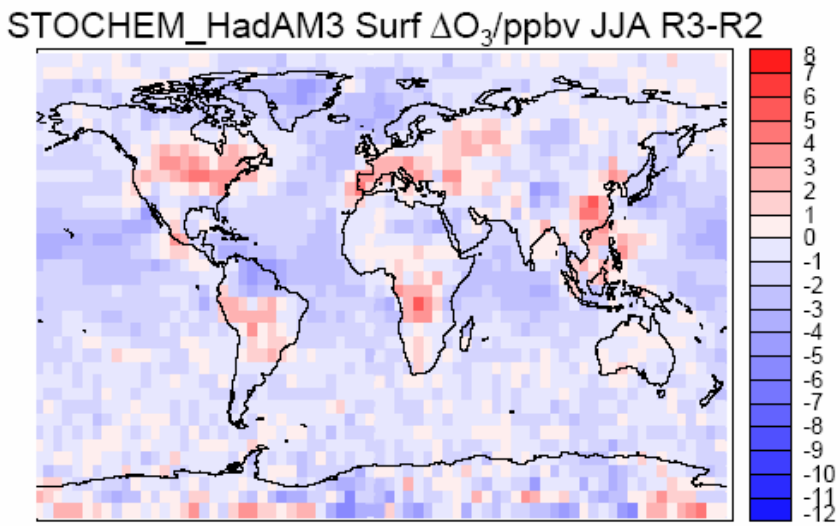


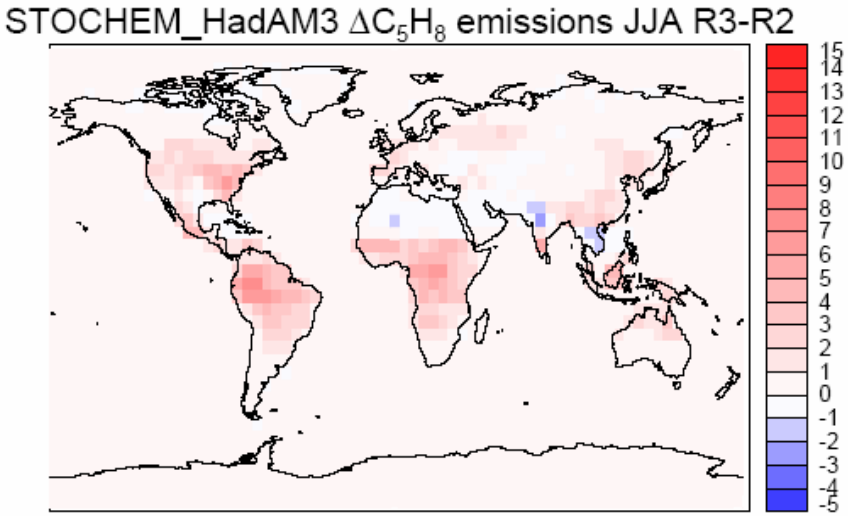
Fractional change in isoprene emission v T0



ΔC_5H_8 emissions and ΔO_3



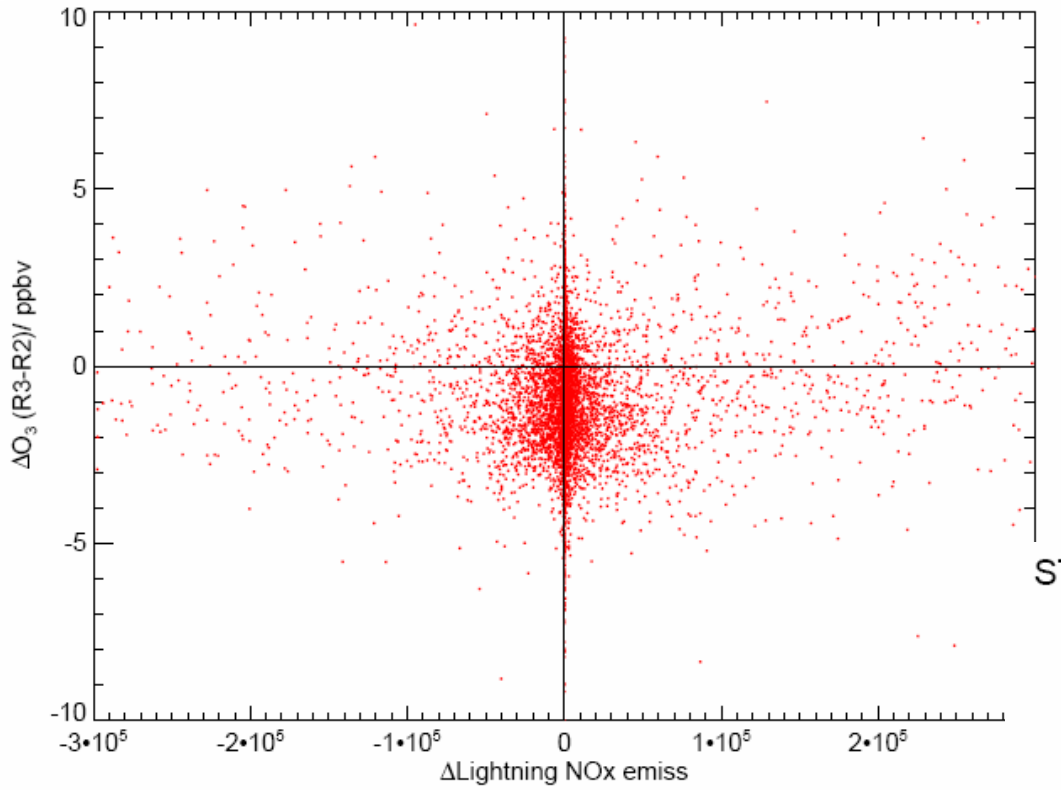


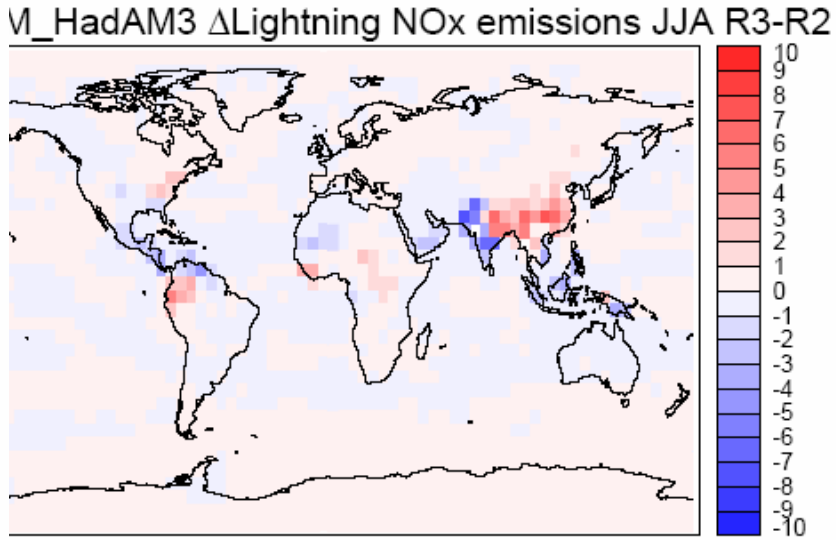


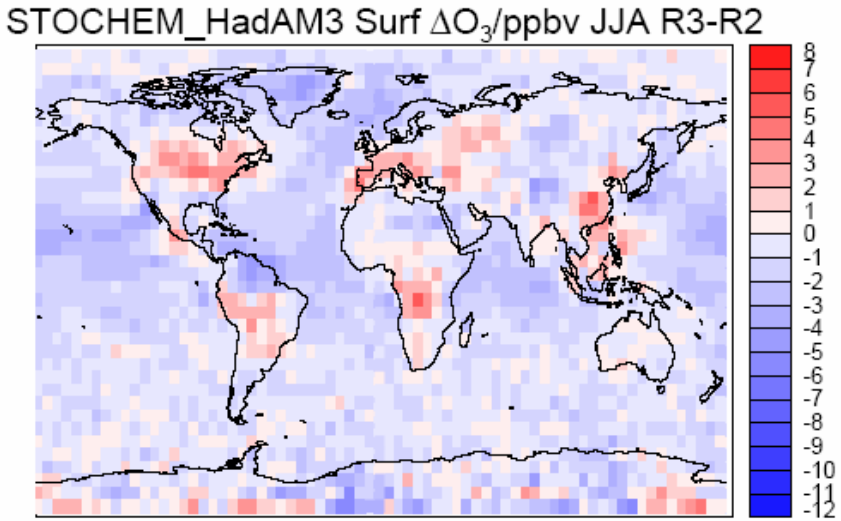
Isoprene needs NO_x to produce O_3?

(Colour above diagram with [NOx])

Changes in lightning NO_x

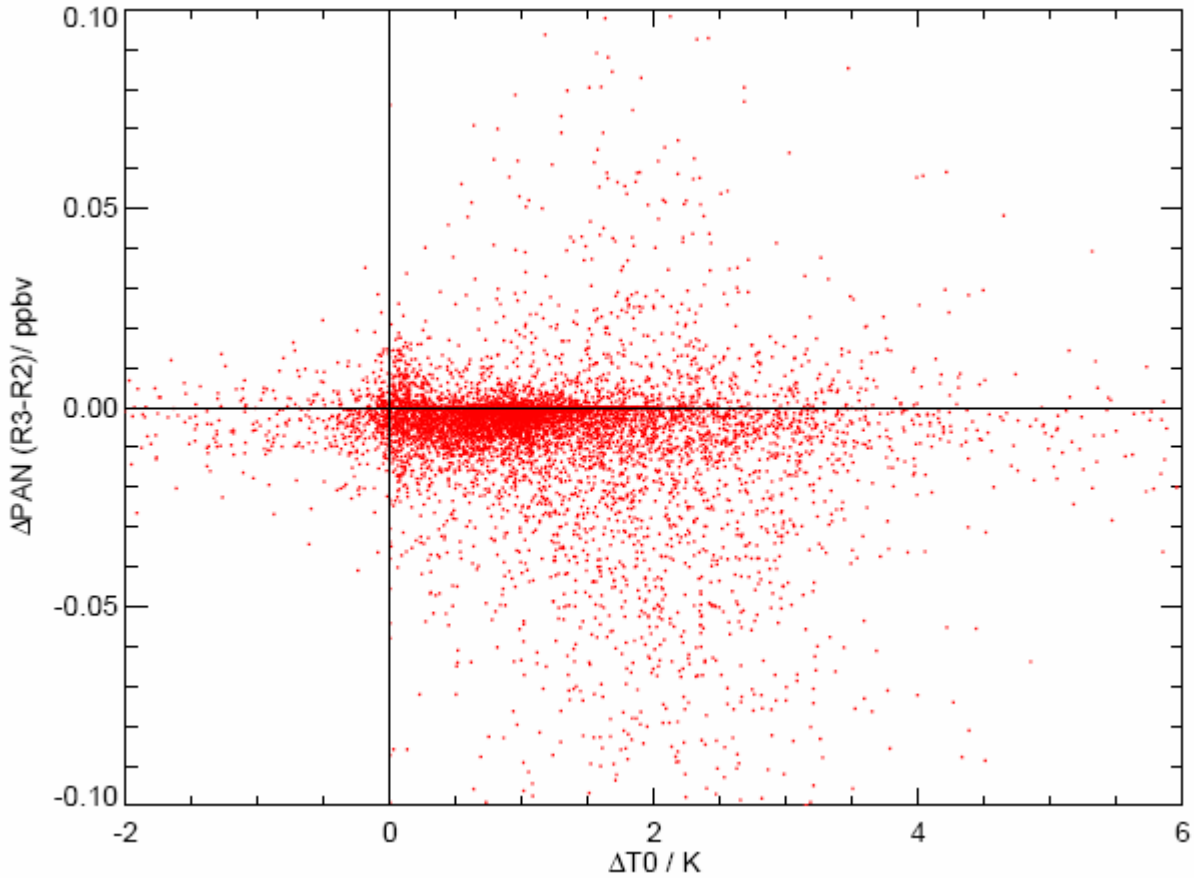






Not a clear relation between lightning NO_x and O_3.

ΔPAN v ΔT0



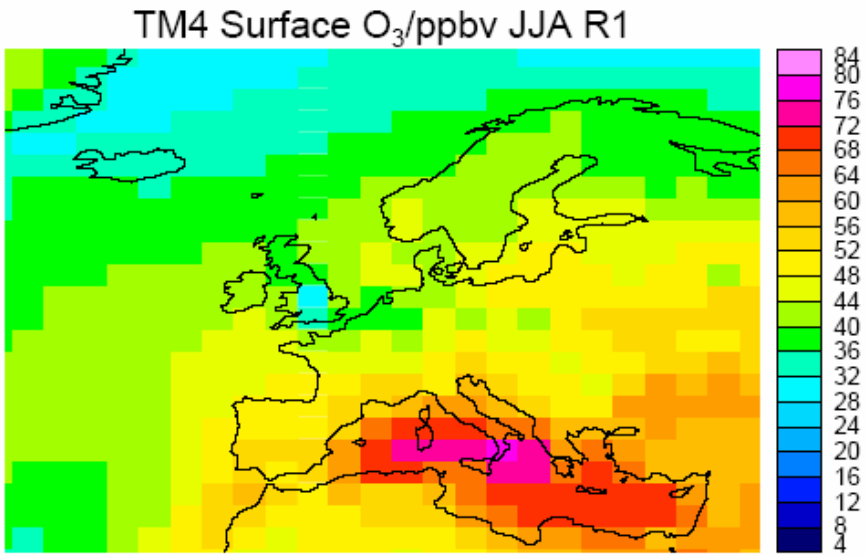
PAN tends to reduce as T0 increases.

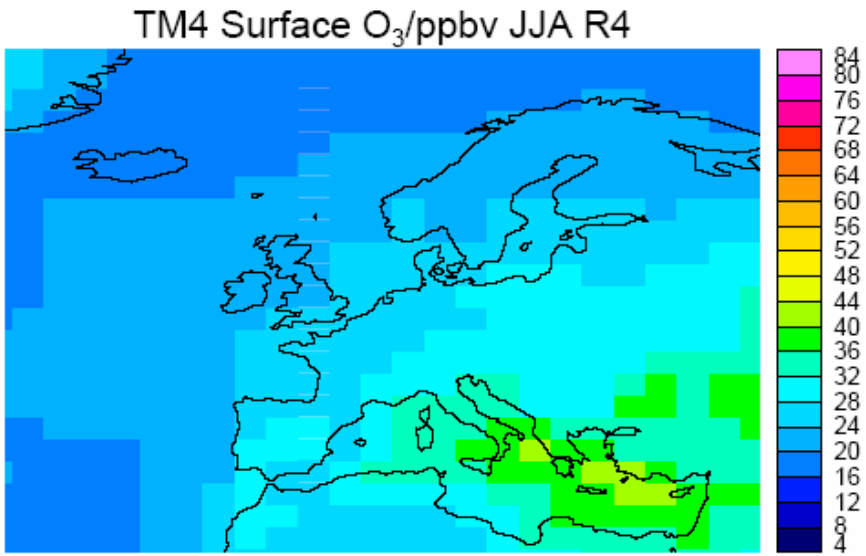
PAN decomposition is T-dependent

PAN → NO_2 + PA

Liberating NO_2

Changes in O_3 since pre-industrial





N. Europe: 20-28 ppbv → 36-52 ppbv

S. Europe: 24-44 ppbv → 44-80 ppbv

Approximately a doubling

PI may be even lower (fixed soil NOx, burning)

Bullet points for report

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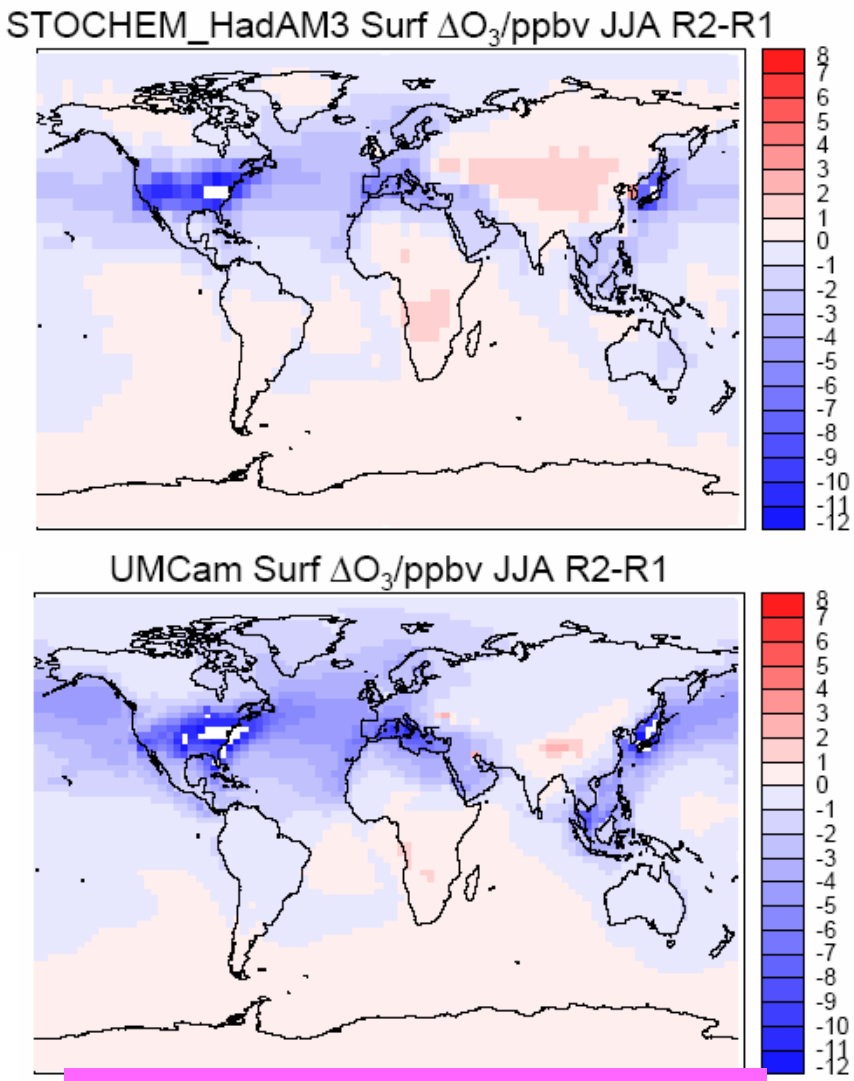
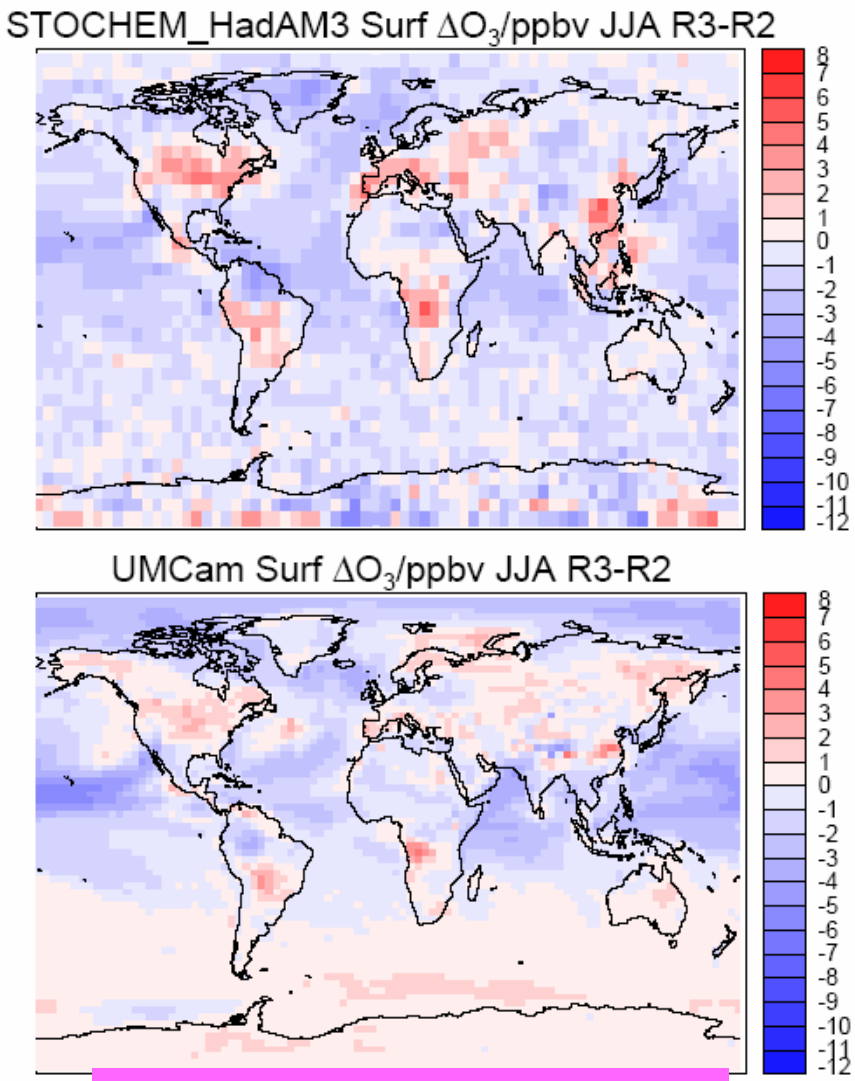
  - Emissions (probably largest uncertainty?)
    - NO_x and CH_4 crucial (VOCs & CO less so?)
    - Surface O_3 has roughly doubled since pre-industrial
  - Climate change - in general:
    - Negative feedback over the tropical oceans (water vapour)
    - (Positive feedback from enhanced strat-trop exchange)
    - Positive feedback over land, particularly polluted areas (mechanisms not yet clear - temperature: PAN $\rightarrow$ NO_x; biogenic VOC; water vapour; lightning NO_x has a variable impact)
  - For the 2050 scenario considered here, improvements in O_3 from emissions controls may be largely reversed or even overturned by climate impacts
  - Possible impacts from land use change (e.g. biomass burning) and stratospheric change not seriously addressed yet

Change in JJA O_3 2050-2000 due to changes in emissions / climate



Emissions change 2000-2050



Climate change 2000-2050