Hemispheric Transport of Ozone Pollution:

Multi-model Assessment of the Role of Methane and the Conventional Ozone Precursors

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Quadrennial Ozone Symposium, Tromsø, Norway, July 2, 2008

Evidence of intercontinental transport at northern midlatitudes: 2001 Asian dust event

Dust leaving the Asian coast in April 2001

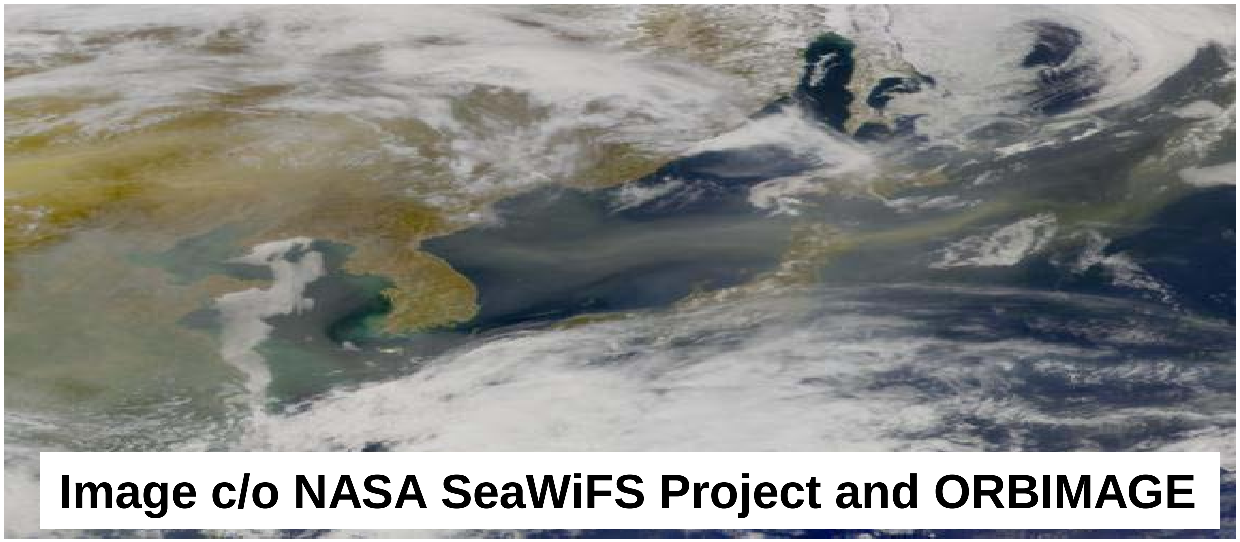
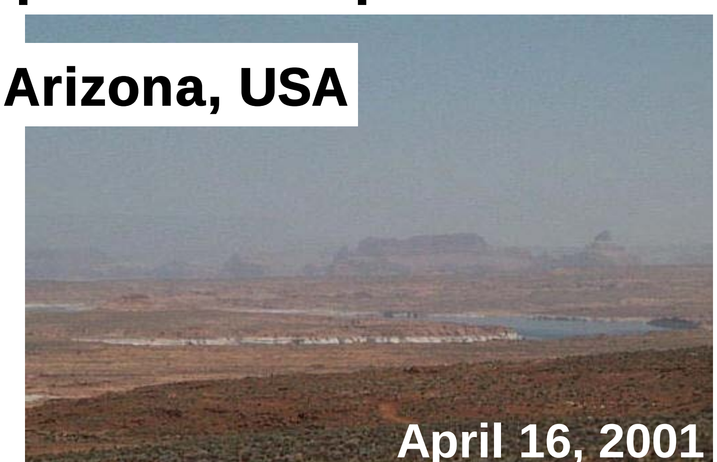


Image c/o NASA SeaWiFS Project and ORBIMAGE

Reduced Visibility from Transpacific Transport of Asian Dust

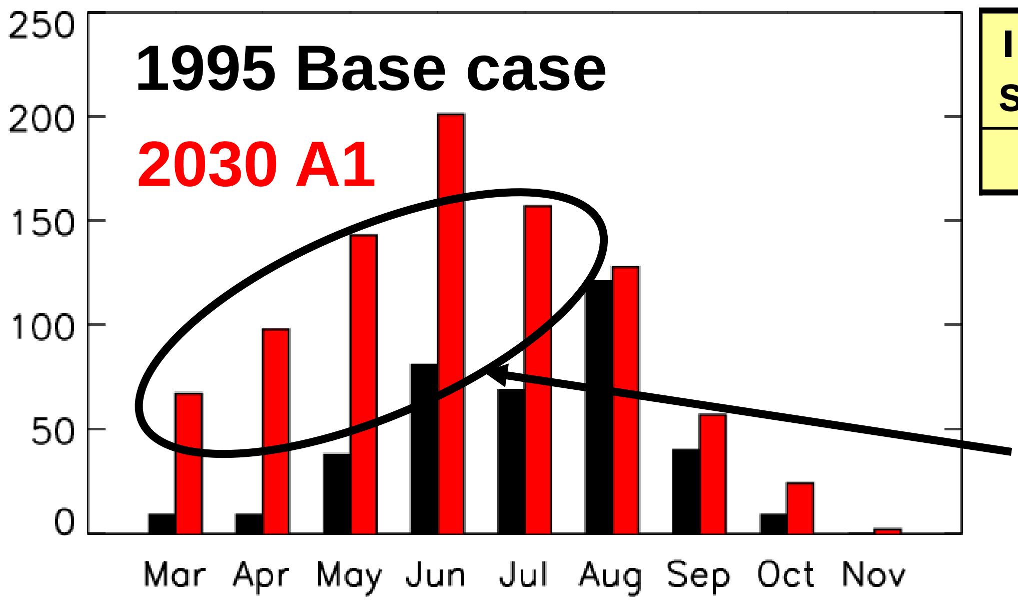
Glen Canyon, Arizona, USA



Regional control efforts (even under optimistic scenarios) may be offset by increases in hemispheric ozone pollution

By 2030 under the CLE scenario (considers air pollution regulations),
"the benefit of European emission control measures is… significantly counterbalanced by increasing global O_3 levels…"
[*Szopa et al.*, *GRL*, 2006]

U.S. grid-square days > 70 ppb



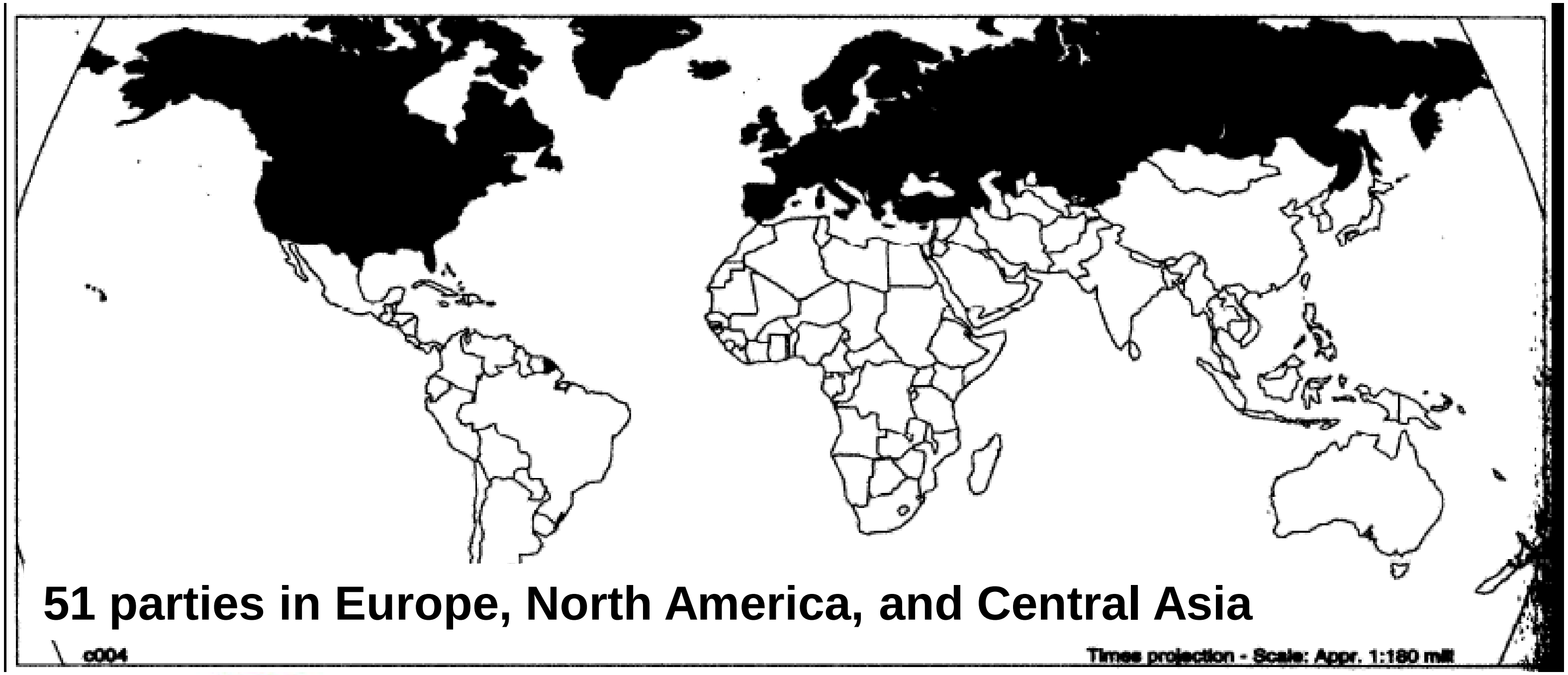
IPCC 2030 Scenario	Anthrop. NO_x emis. Global	U.S.	Methane emis.
A1	+80%	-20%	+30%

GEOS-Chem Model (4°x5°)
[*Fiore et al., GRL*, 2002]

U.S. air quality degrades despite domestic emissions controls (A1 2030)

→ International approach to ozone abatement?

Convention on Long-Range Transboundary Air Pollution (CLRTAP)



51 parties in Europe, North America, and Central Asia

Task Force on Hemispheric Transport of Air Pollution

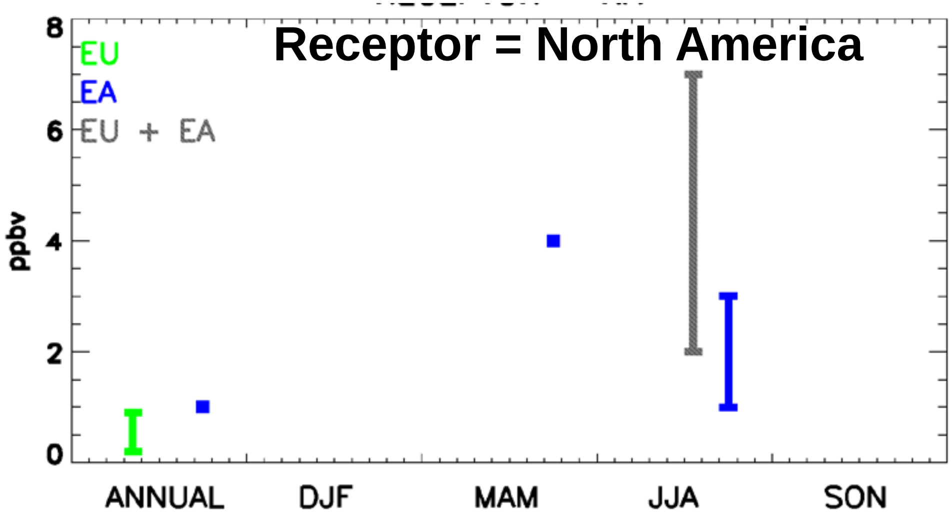
Co-chairs: Terry Keating (U.S. EPA) and André Zuber (EC)

TF HTAP Mission: Develop a fuller understanding of hemispheric transport of air pollution to inform future negotiations under CLRTAP

www.htap.org for more information + 2007 TF HTAP Interim Report

Wide range in prior estimates of intercontinental surface ozone source-receptor (S-R) relationships

[redacted]



Estimates are from studies cited in TF HTAP [2007] Ch5, plus new work [*Holloway et al.*, 2008; *Duncan et al.*, 2008; *Lin et al.*, 2008]

Assessment hindered by different:

1) **methods**
2) **regional definitions**
3) **reported metrics**
4) **years (meteorology)**

→ Adopt a multi-model approach
→ Consistency across models
→ Examine all seasons

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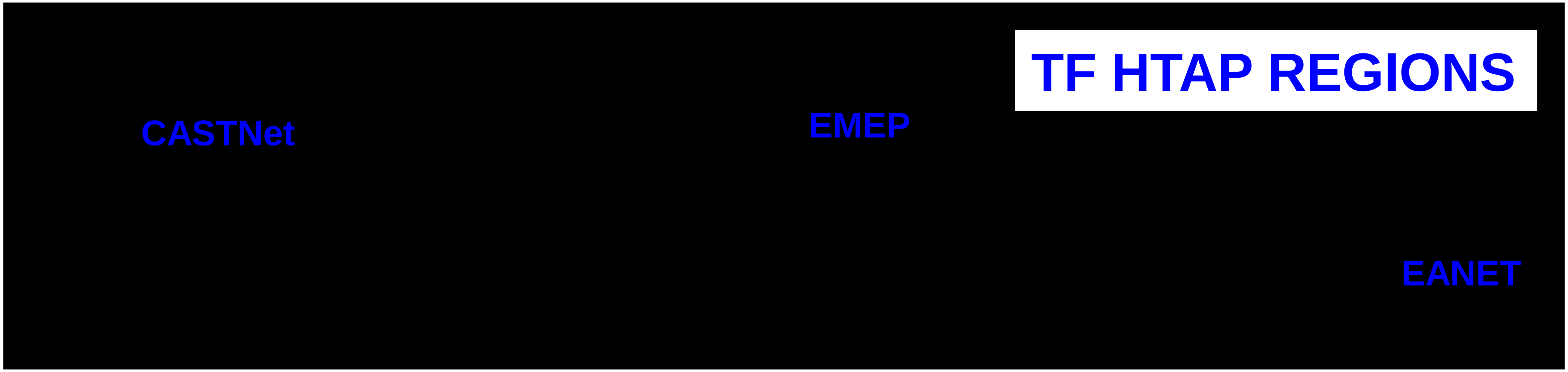
Objective: Quantify & assess uncertainties in N. mid-latitude S-R relationships for ozone



BASE SIMULATION (21 models):

- → horizontal resolution of 5 x5° or finer
- → 2001 meteorology
- → each group's best estimate for 2001 emissions
- → methane set to 1760 ppb

SENSITIVITY SIMULATIONS (13-18 models):

- → -20% regional anthrop. NO_x, CO, NMVOC emissions, individually + all together (=16 simulations)
- → -20% global methane (to 1408 ppb)

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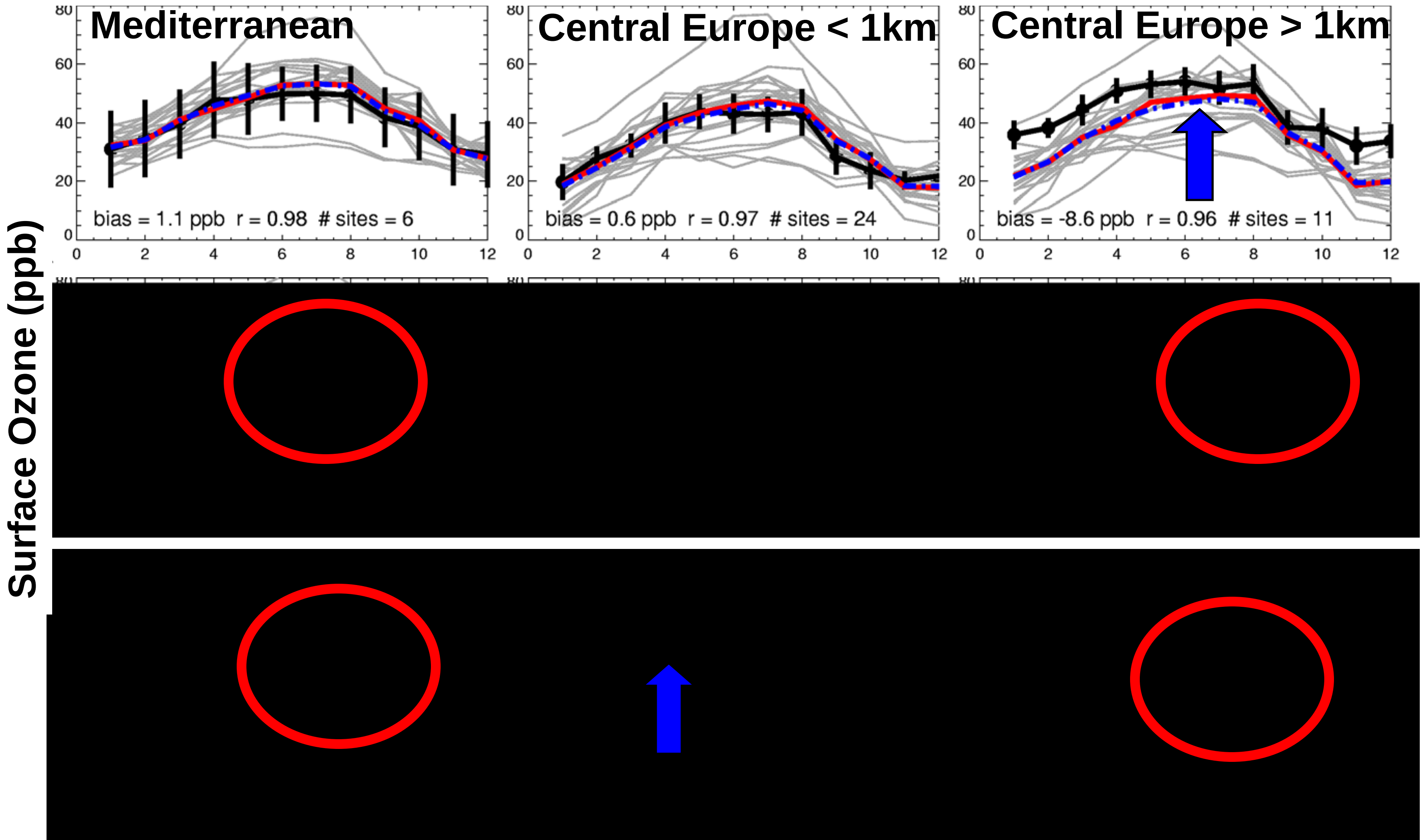
Large inter-model range; multi-model mean generally captures observed monthly mean surface O_3



- → Many models biased low at altitude, high over EUS+Japan in summer
- → Good springtime/late fall simulation

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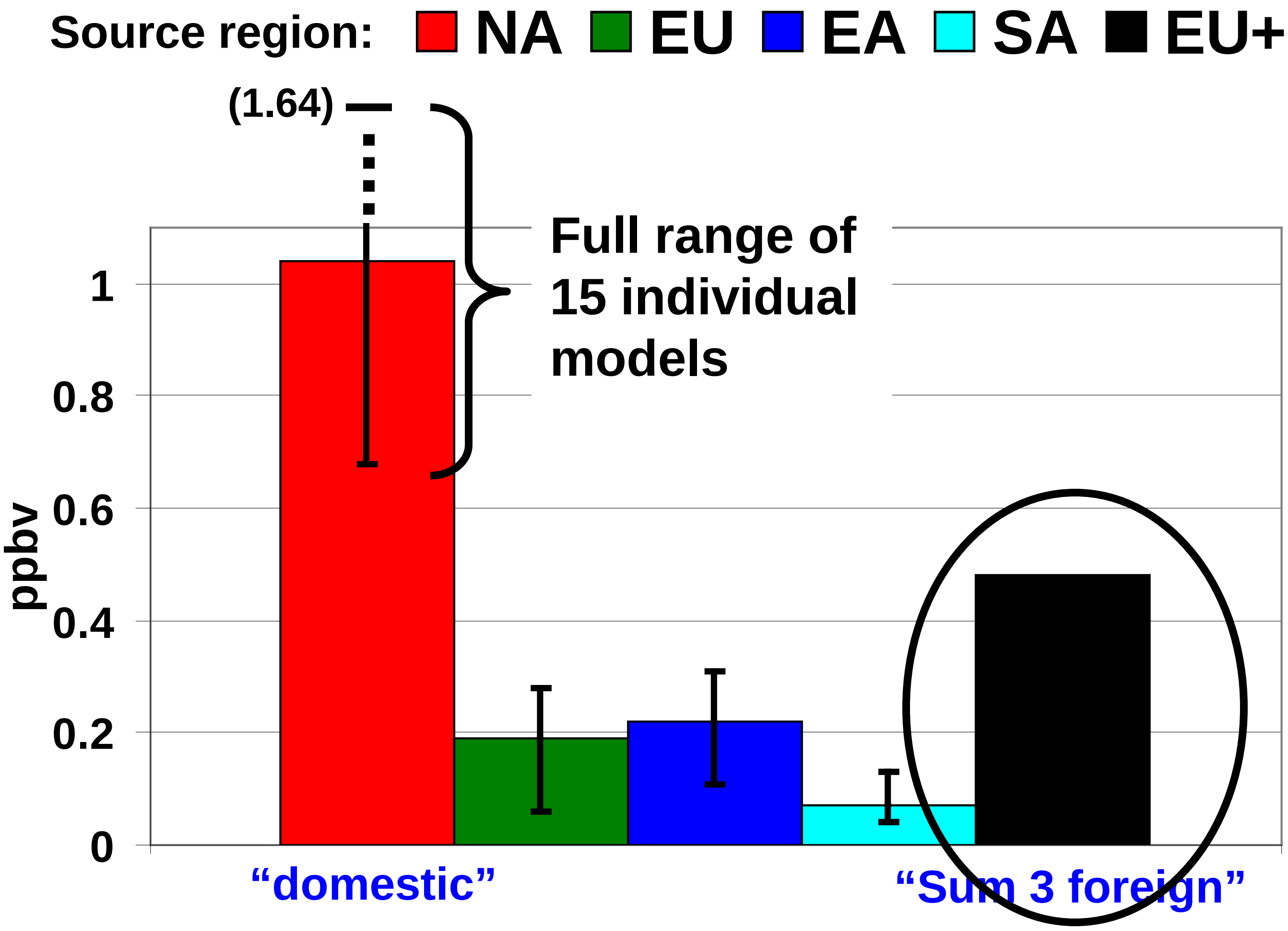
North America as a receptor of ozone pollution: Annual mean foreign vs. domestic influences

Annual mean surface O_3 decrease from -20% NOx+CO+NMVOC regional anthrop. emissions



"import sensitivity"

$$\frac{\sum 3\ \text{foreign}}{\text{domestic}} = 0.45$$

Seasonality?

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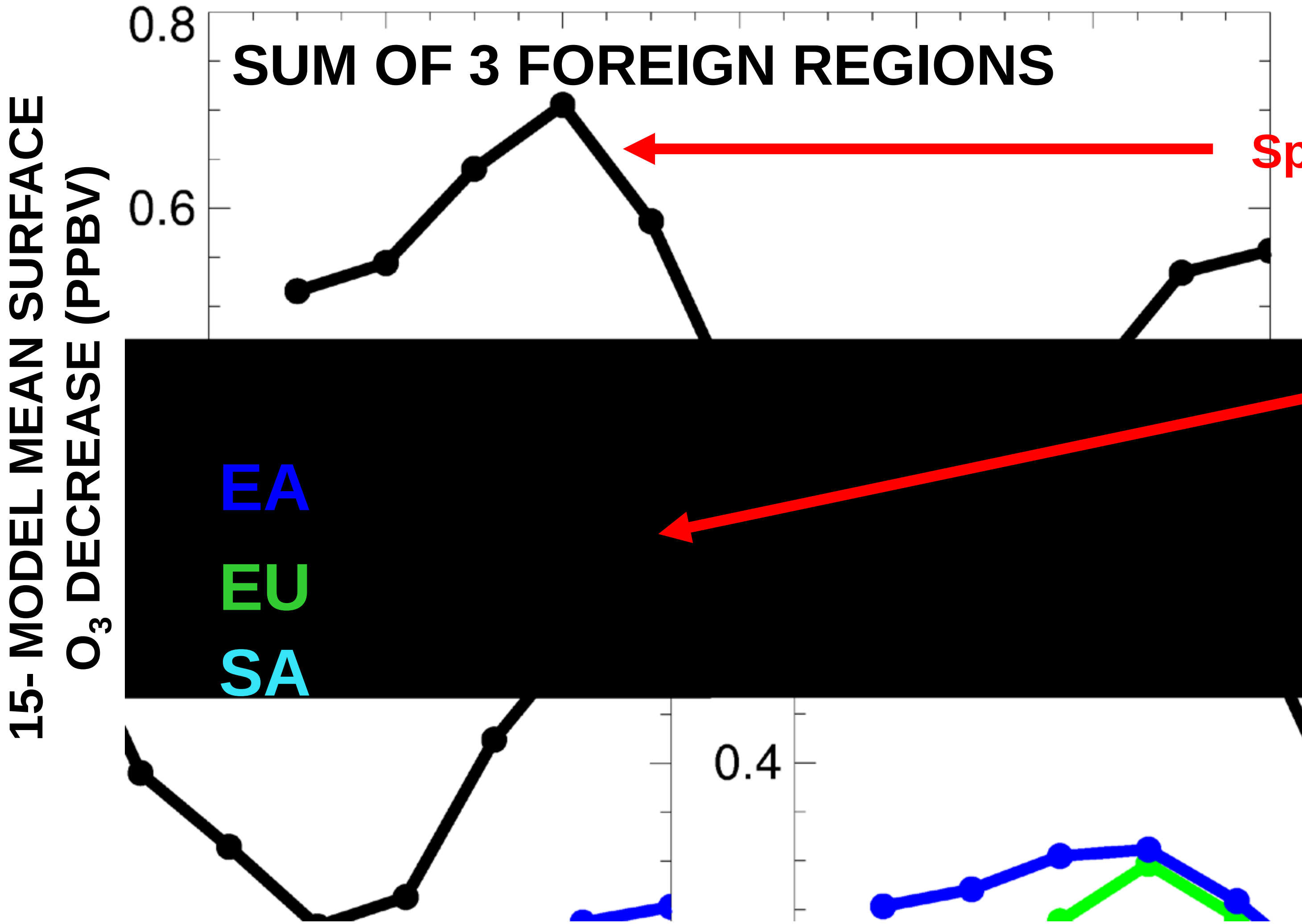
North America as a receptor of ozone pollution: Seasonality of response to -20% foreign anthrop. emissions



Spring max

Similar response to EU & EA emissions Apr-Nov (varies by model)

Spring (fall) max due to longer O_3 lifetime, efficient transport

[e.g., Wang et al., 1998; Wild and Akimoto, 2001; Stohl et al., 2002; TF HTAP 2007]

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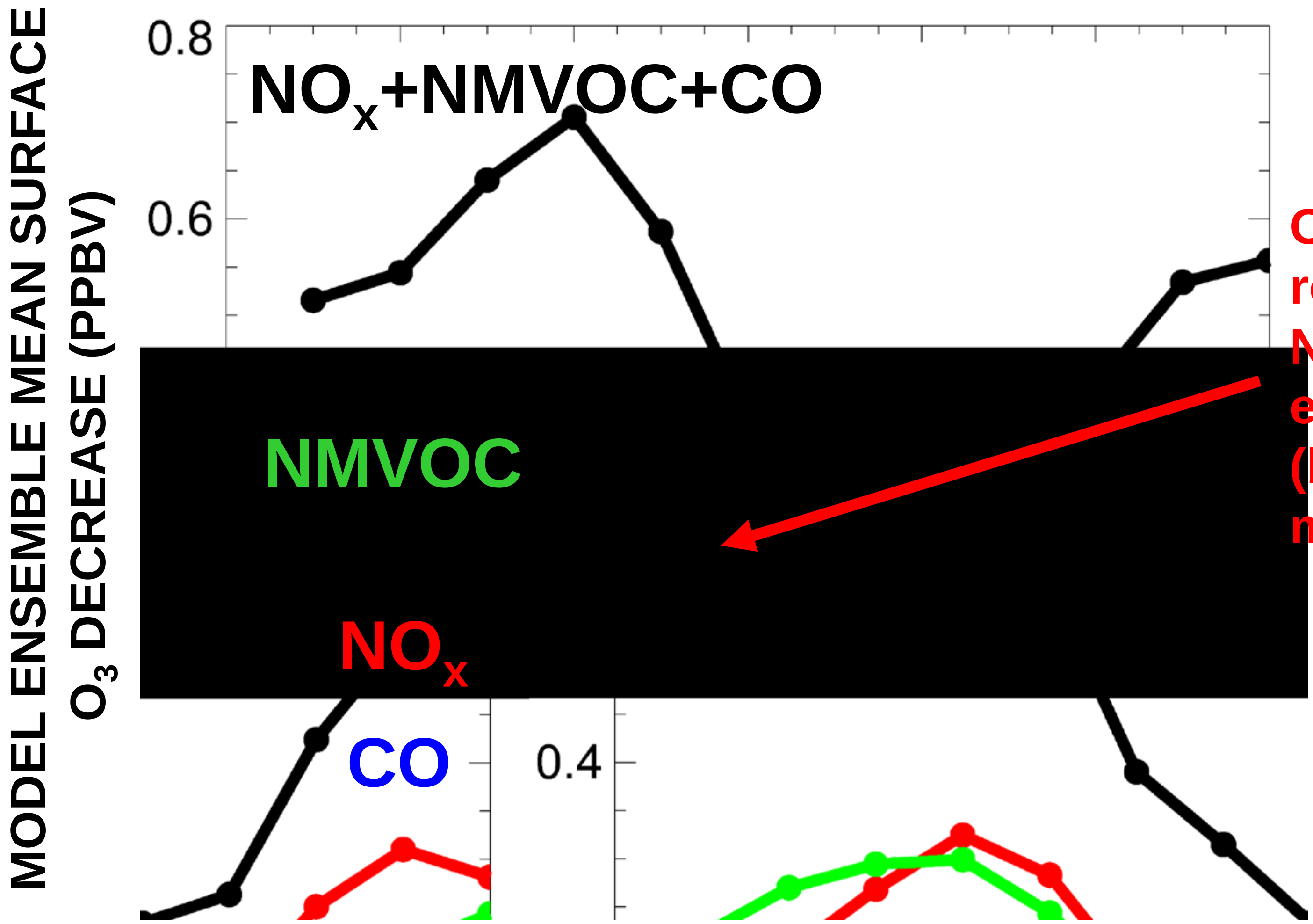
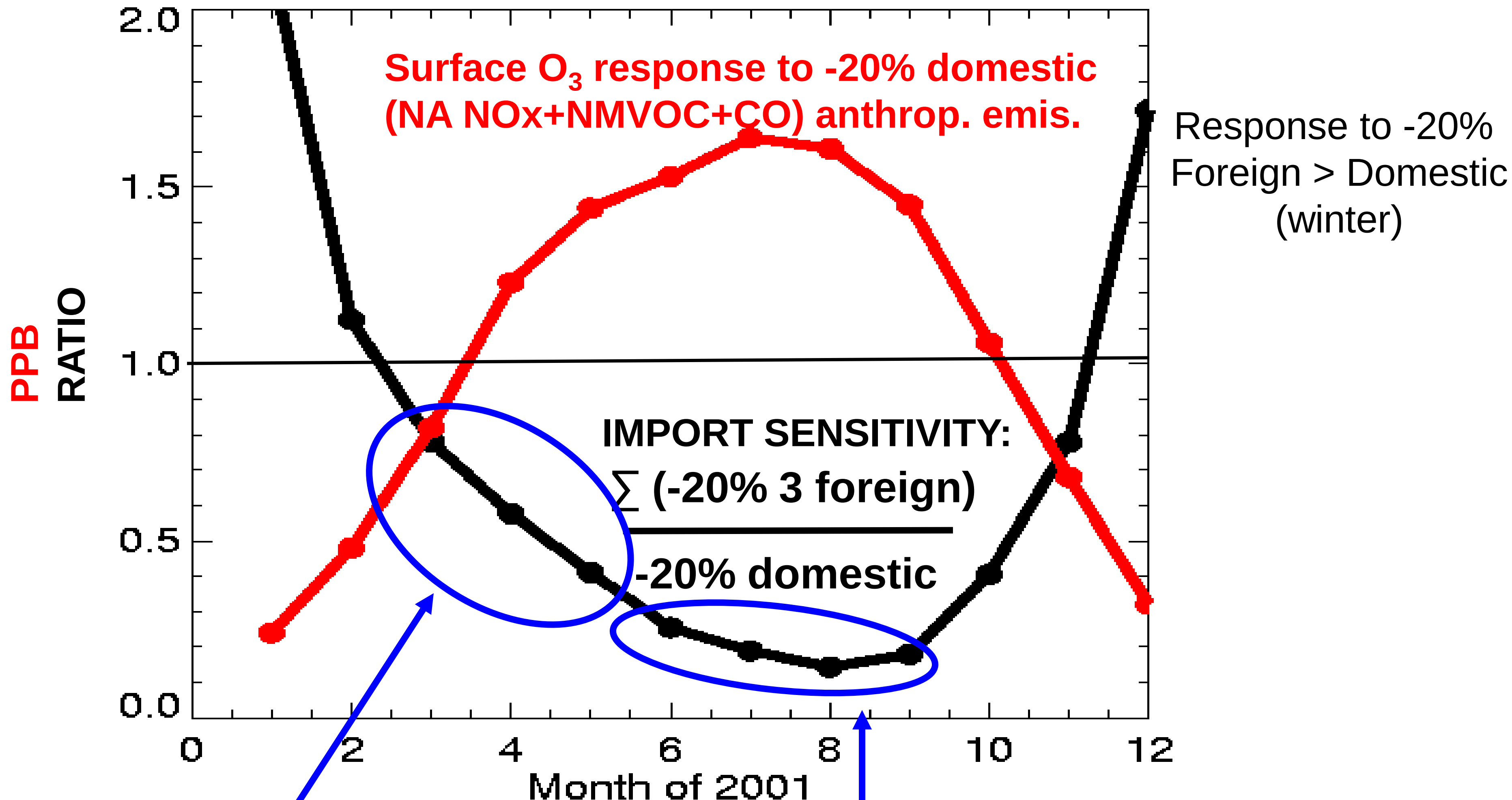
North America as a receptor of ozone pollution: Seasonality of response to -20% foreign anthrop. emissions



Comparable response to NO_x & NMVOC emissions (but varies by model)

Wide range in EU anthrop. NMVOC inventories
→ large uncertainty in the estimated response of NA O_3

North America as a receptor of ozone pollution: Seasonality in "import sensitivity"



0.4-0.8 during spring "high transport season"

~0.2 when domestic O_3 production peaks in summer

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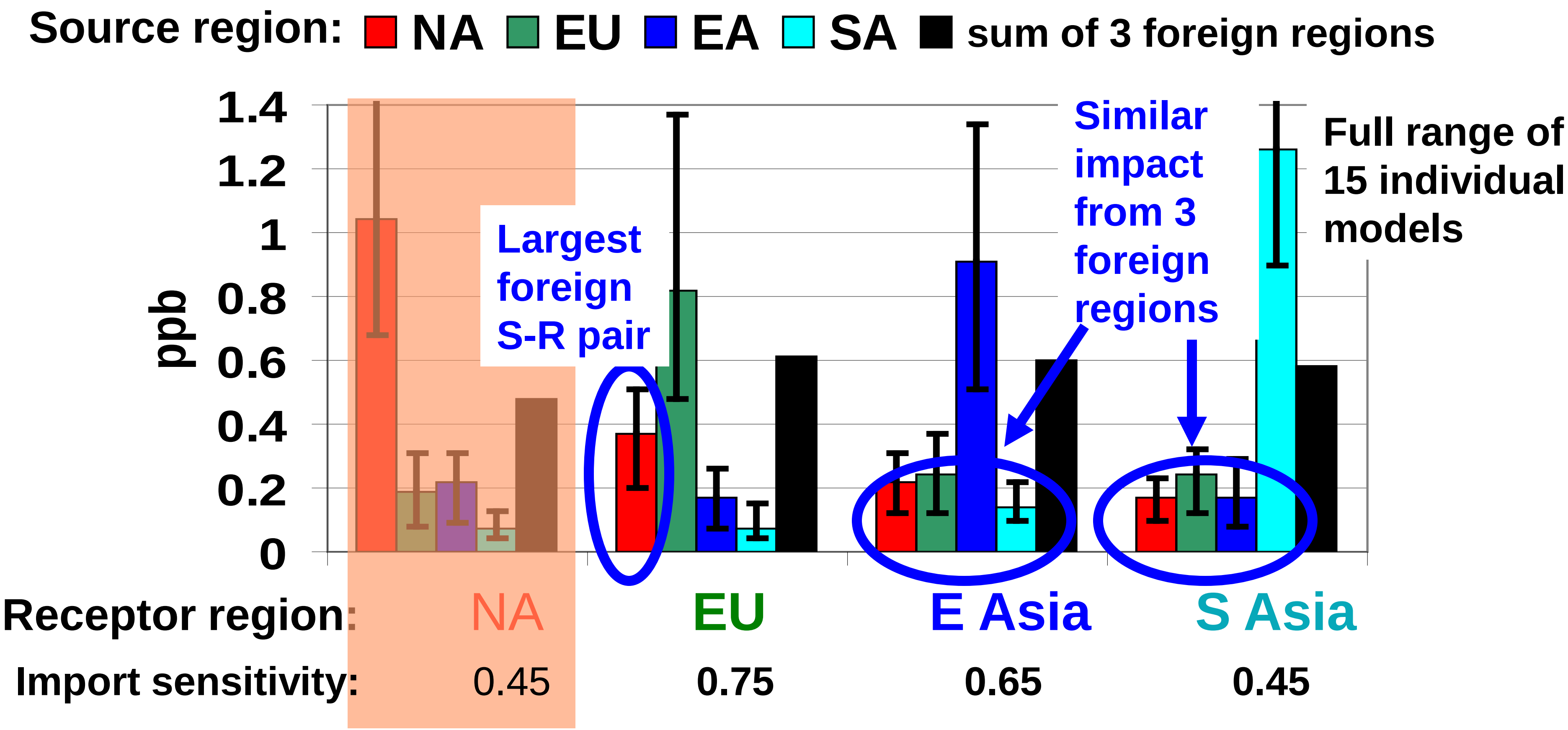
Estimates of S-R relationships for surface O_3 pollution

Annual mean surface O_3 decrease from -20% NOx+CO+NMVOC regional anthrop. emissions



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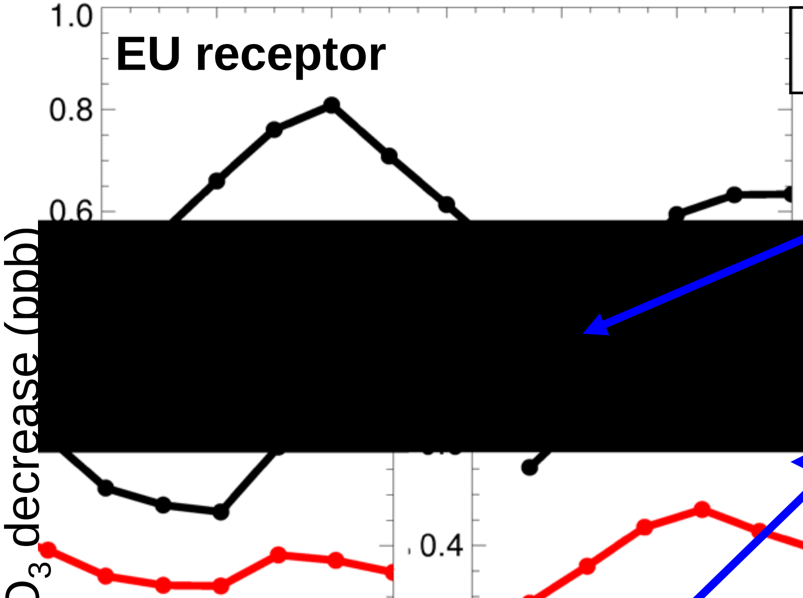
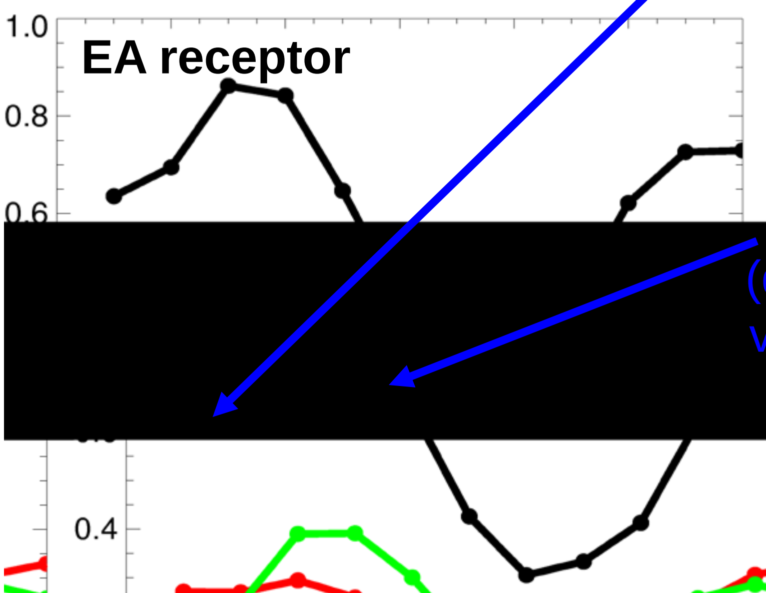
Surface O_3 response to decreases in foreign anthropogenic emissions of O_3 precursors

Source region: SUM3 NA EA EU SA

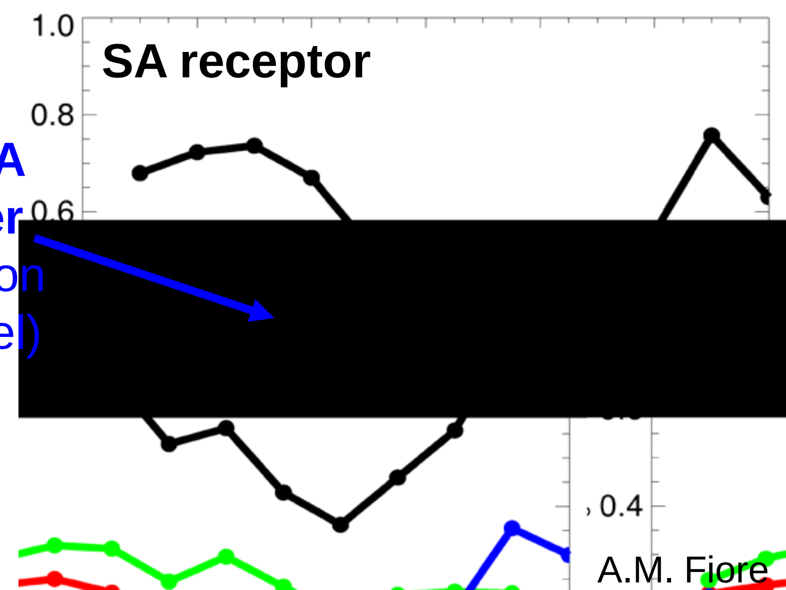


NA>EA>SA over EU (robust across models)

response typically smallest to SA emis.
(robust across models)



NA & EU often > SA/EA on each other
(dominant region varies by model)



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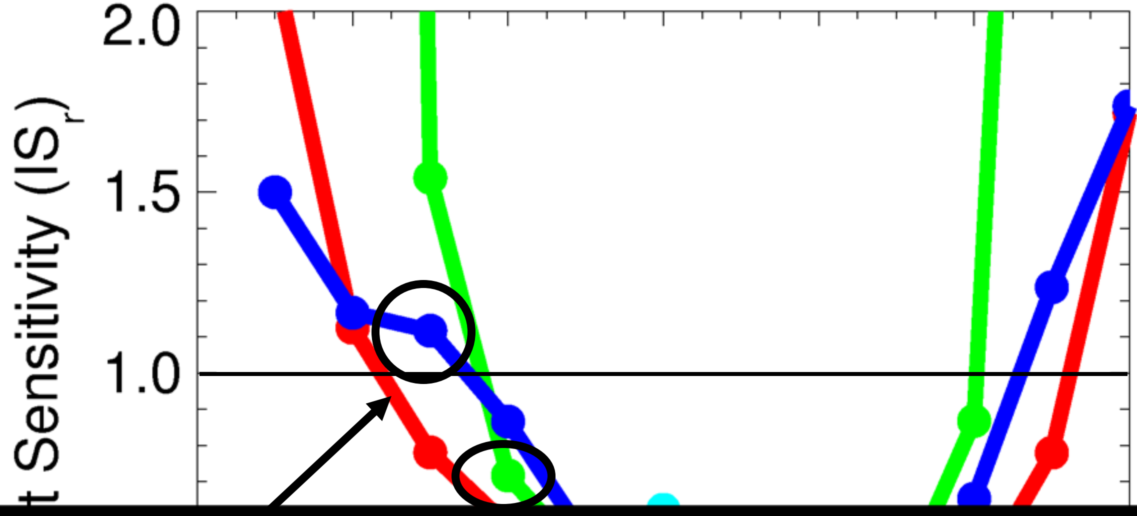
Monthly mean import sensitivities



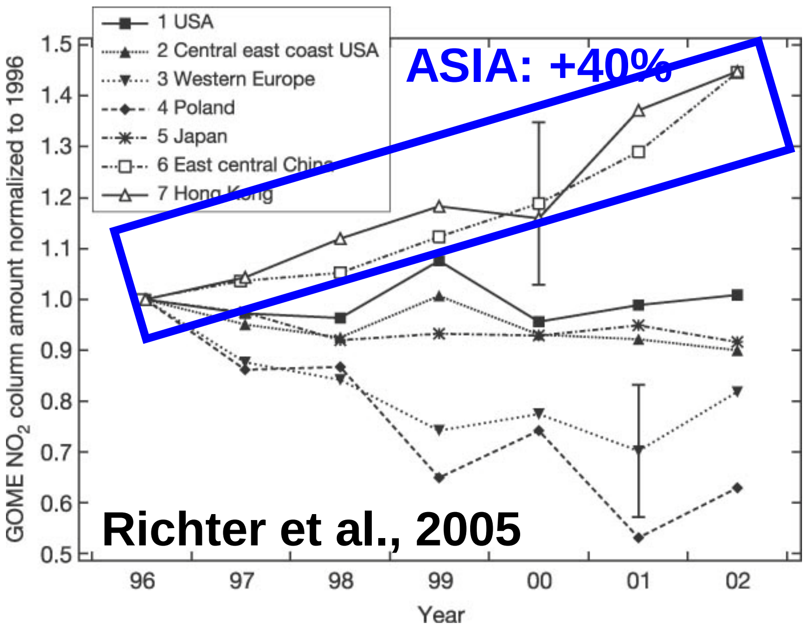
[redacted] SA fairly constant ~0.5

1.1 (EA), [redacted] month with max response to foreign emissions

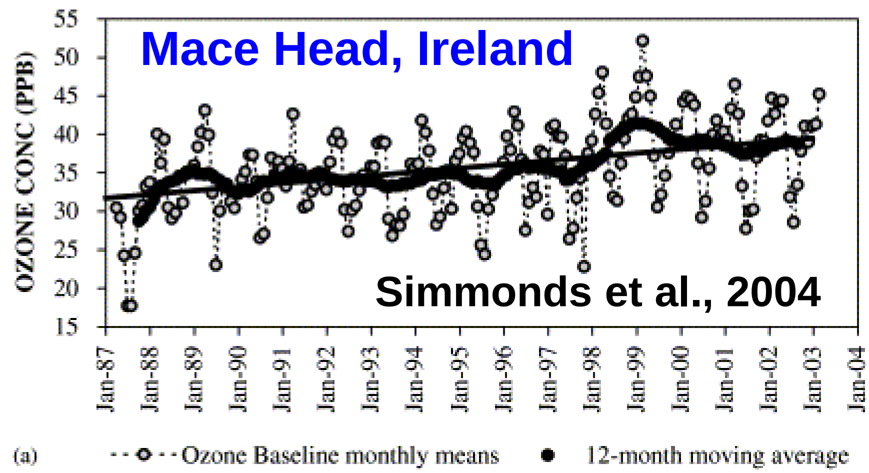
[redacted] ring month of max response to domestic emissions

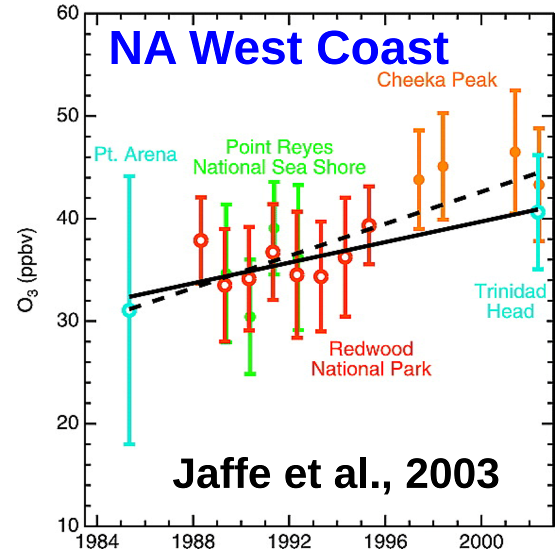
Application of S-R relationships: Consistency between background O_3 trends and reported changes in Asian emissions?

SPACE-BASED NO_2 → NO_x EMISSIONS



OBSERVED: +0.1-0.5 ppb yr^{-1} in background surface O_3 [TF HTAP, 2007]





Assuming +10% yr^{-1} Asian emissions, our results imply an O_3 increase over NA and EU of at most 0.15 ppb yr^{-1}

OUR CAVEATS:

-- assumes SA+EA, + other emissions follow NO_x

-- continental-avg vs. “west coast” obs

Fig 3.6 from TF HTAP [2007]

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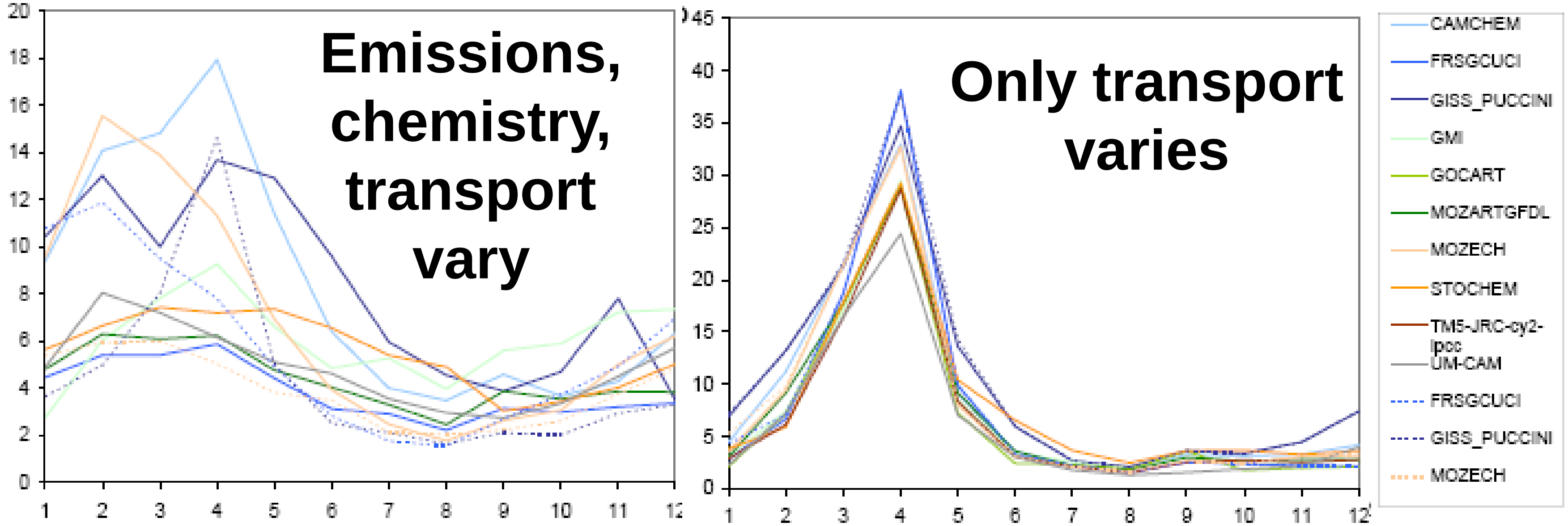
Addressing Uncertainties: Quantifying model differences due to transport (vs. emissions and chemistry)

Example: SA → EA for CO



Model results averaged from surface to 1 km

POSTER by Martin Schultz *et al*.:
Passive tracer simulations in the context of the TF HTAP multi-model assessment activity

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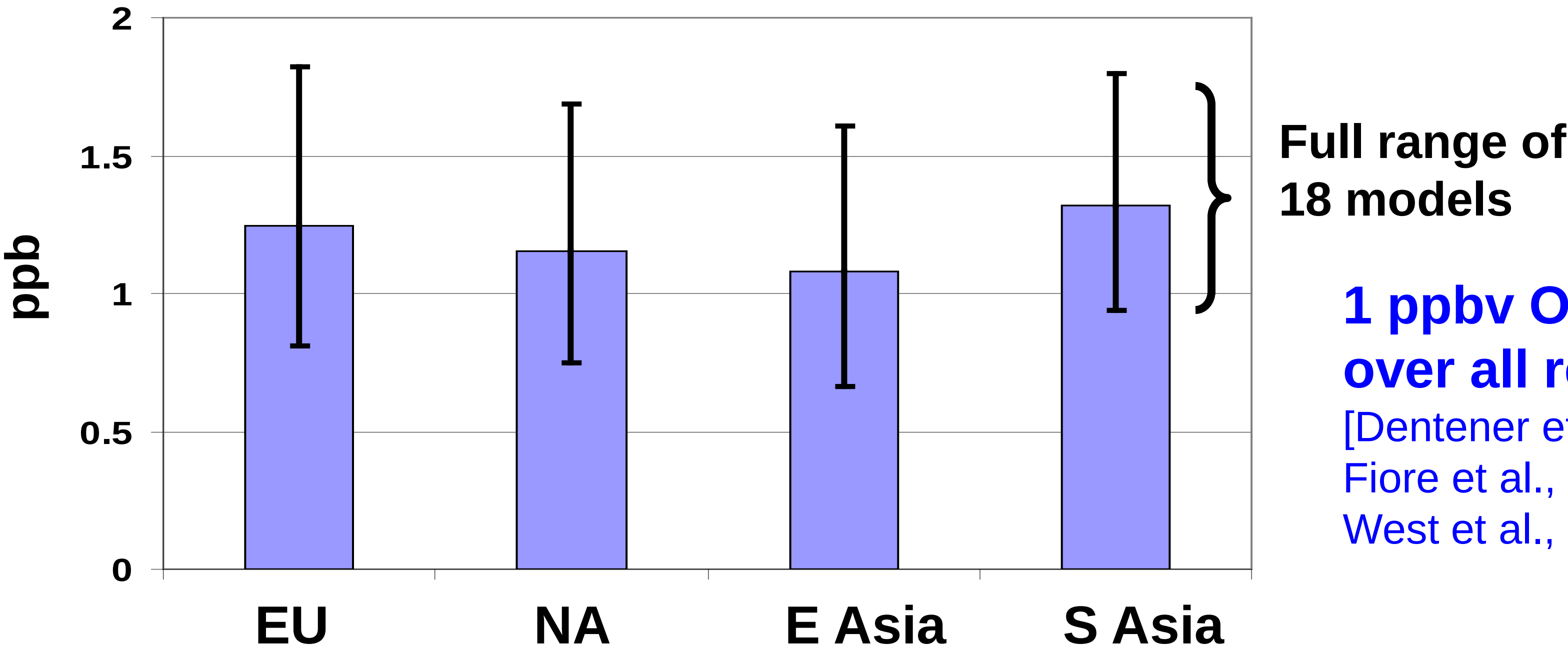
Surface ozone response to -20% global [CH_4]: similar decrease over all regions



1 ppbv O_3 decrease over all regions
[Dentener et al.,2005; Fiore et al., 2002, 2008; West et al., 2007]

Estimate O_3 response to -20% regional CH_4 anthrop. emissions to compare with O_3 response to NOx+NMVOC+CO:

(1) -20% global [CH_4] ≈ -25% global anthrop. CH_4 emissions
(2) Anthrop. CH_4 emis. inventory [Olivier et al., 2005] **for regional emissions**
(3) Scale O_3 response (linear with anthrop. CH_4 emissions [Fiore et al., 2008]**)**

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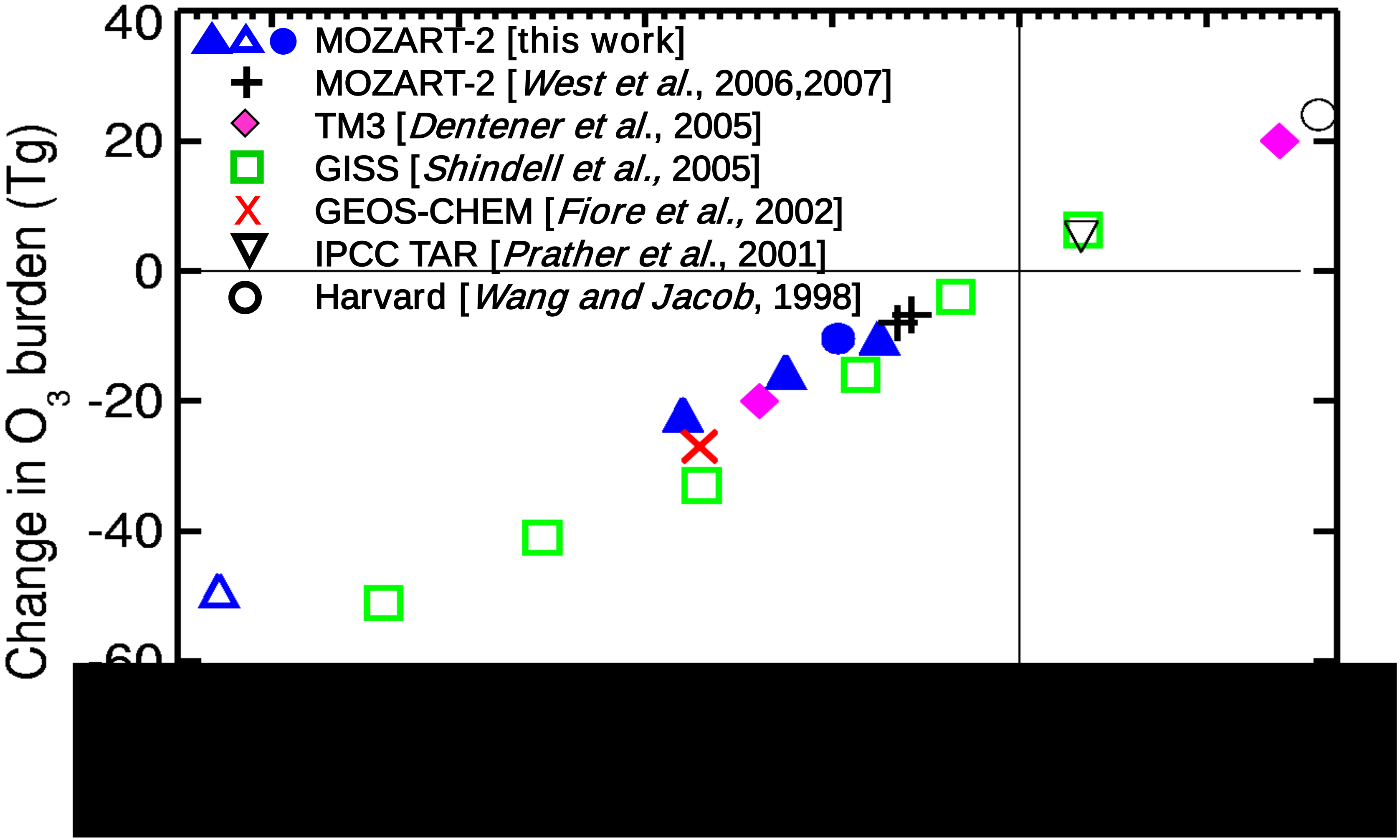
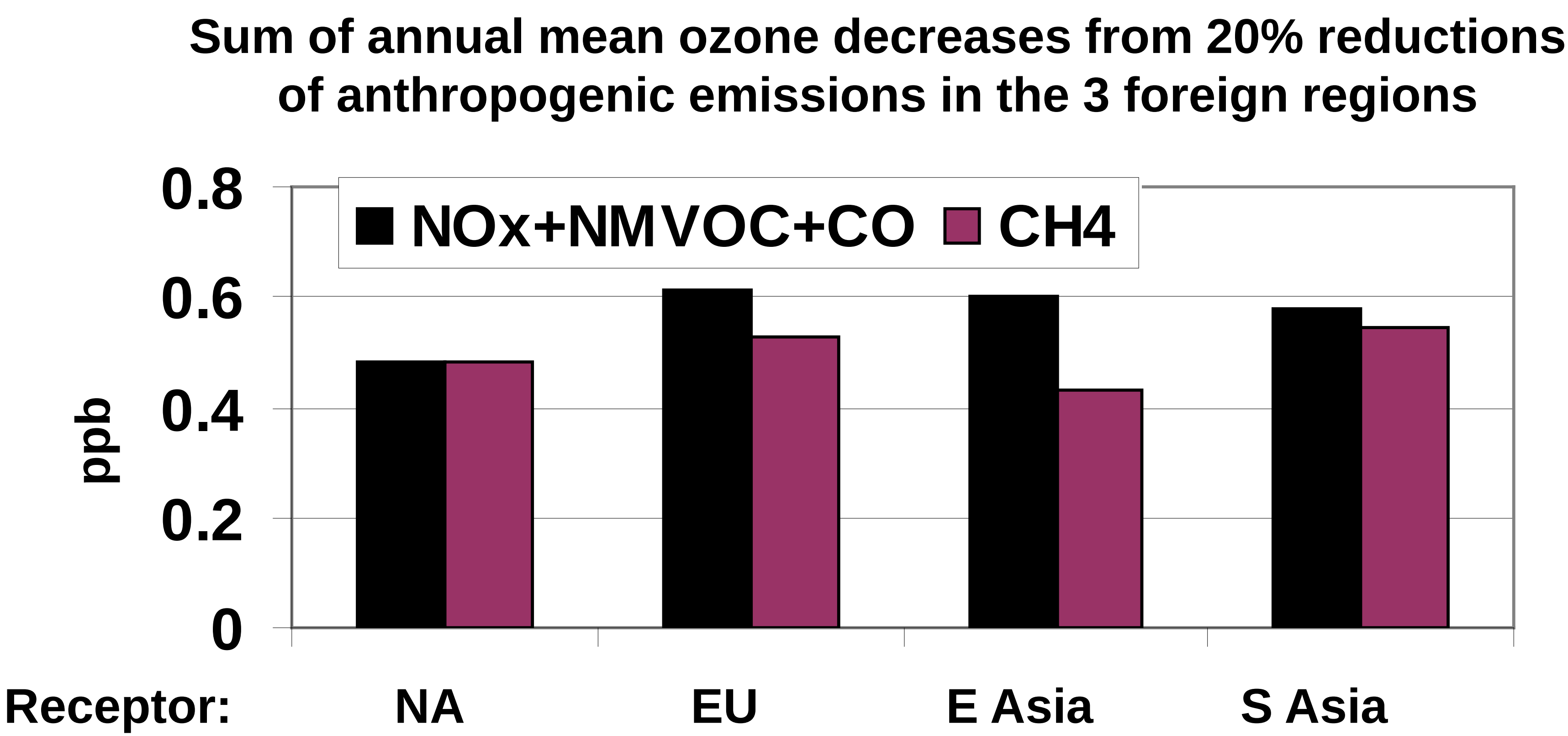
Tropospheric O_3 responds approximately linearly to anthropogenic CH_4 emission changes across models



Anthropogenic CH_4 contributes ~50 Tg (~15%) to tropospheric O_3 burden
~5 ppbv to surface O_3

Fiore et al., *JGR*, 2008

Comparable annual mean surface O_3 response to -20% foreign anthropogenic emissions of CH_4 vs. NO_x+NMVOC+CO



(Uses CH_4 simulation + anthrop. CH_4 emission inventory [*Olivier et al*., 2005] to estimate O_3 response to -20% regional anthrop. CH_4 emissions)

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Conclusions: Hemispheric Transport of O_3

www.htap.org for more information + 2007 TF HTAP Interim Report

- **Benchmark for future: Robust estimates + key areas of uncertainty**
- **"Import Sensitivities" (Δ O_3 from anthrop. emis. in the 3 foreign vs. domestic regions): 0.5-1.1 during month of max response to foreign emis; 0.2-0.3 during month of max response to domestic emissions**
- **Our estimates + emis. trends → low end of observed surface O_3 trends**
- **Comparable O_3 decrease from reducing equivalent % of CH_4 and NOx+NMVOC+CO over foreign regions (0.4-0.6 ppb for 20% reductions)**

ADDITIONAL QUESTIONS (TF HTAP work ongoing for 2010 report):

How well do models capture the relevant processes (e.g. export, chemical evolution, transport, mixing)?

Can we scale our estimated O_3 responses to other combinations and magnitudes of emission changes?

What is the contribution of hemispheric transport to metrics relevant to attainment of O_3 air quality standards?

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