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Atmospheric Chemistry and Physics Discussions

- LESSONS FROM =

Global ozone and air quality: a multi-model assessment of risks to human health and crops

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PhotoComp (2005)

- Focus on the year 2030; 'the inter-mediate' future which is of direct relevance to policy makers; compare to the year 2000
- Emphasis on the synergetic effect of air quality (*human health* and *vegetation* exposure) and climate (RF)
- 26 models from 15 different model "families"; model resolution from 1°x1° to 2.5 °x2.5 ° to 5° x5°. Model statistics- and model response to emissions
- 6 publications
- Baseline + 3 emission scenarios + climate change scenario

Emission scenarios:

CLE: Current Legislation 2030

MFR: Maximum Feasible Reduction 2030

SRES A2: high emission

Climate Change scenario:

IPCC92a (ca 1 K temperature increase) by 2030

Global NO_x emission scenarios

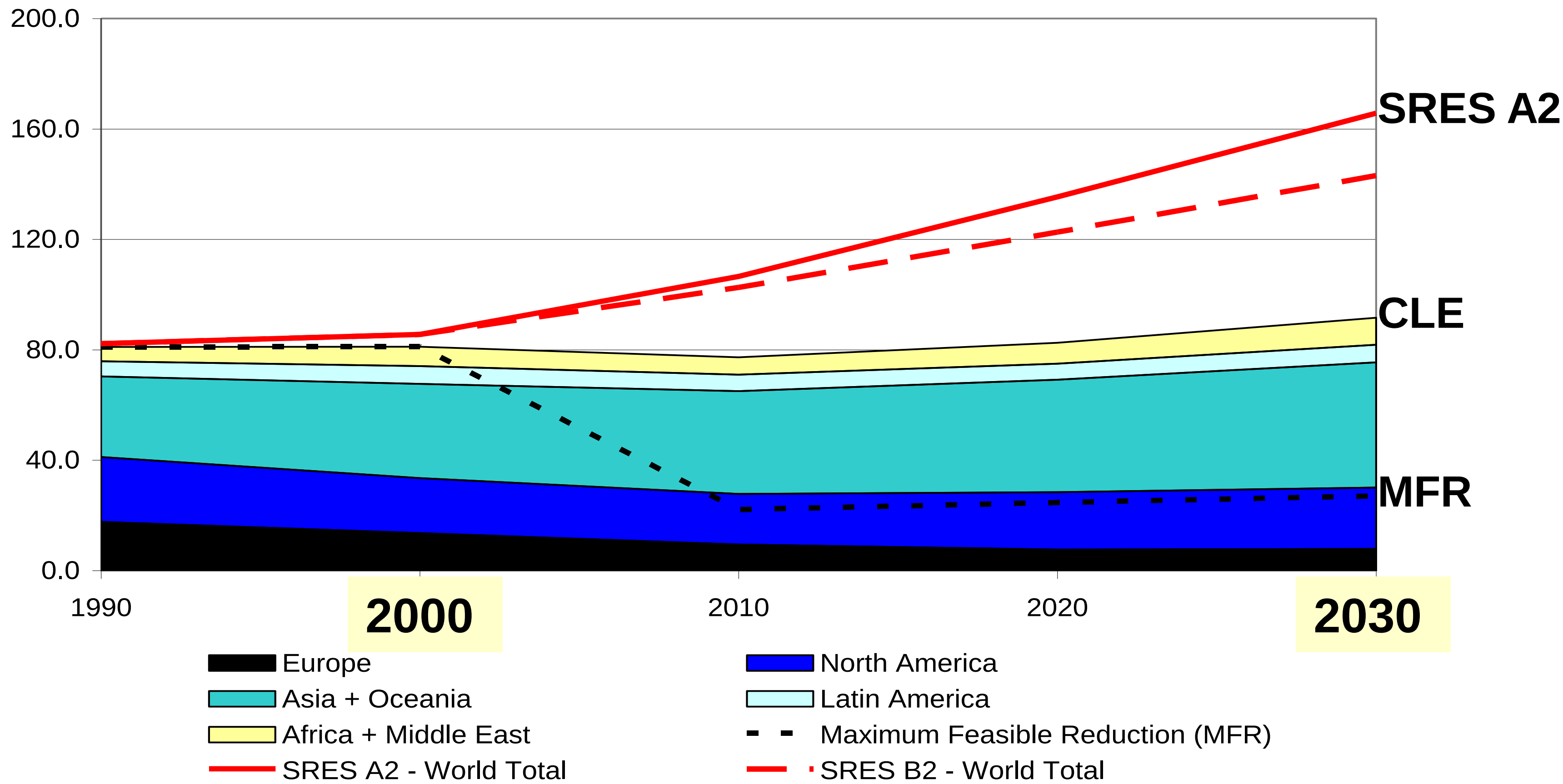


Figure 1. Projected development of IIASA anthropogenic NO_x emissions by SRES world region (Tg NO_2 yr^{-1}).

Analysis of oxidation capacity, surface ozone, deposition, satellite observations of NO2 and CO

Ozone and oxidation capacity:

- 3D monthly mean fields for O3, CO, CH4, NO, NO2, and OH
- Daily average tropospheric column ozone
- 3D monthly budgets of ozone production and destruction, surface deposition, stratospheric O3 influx
- Hourly surface ozone [ppbv]
- 3D monthly mean field of the CH4+OH destruction flux; lifetime, OH

Ecosystem inputs:

Oxidized and reduced nitrogen, and sulfur deposition

Biodiversity, Eutrophication, Acidification

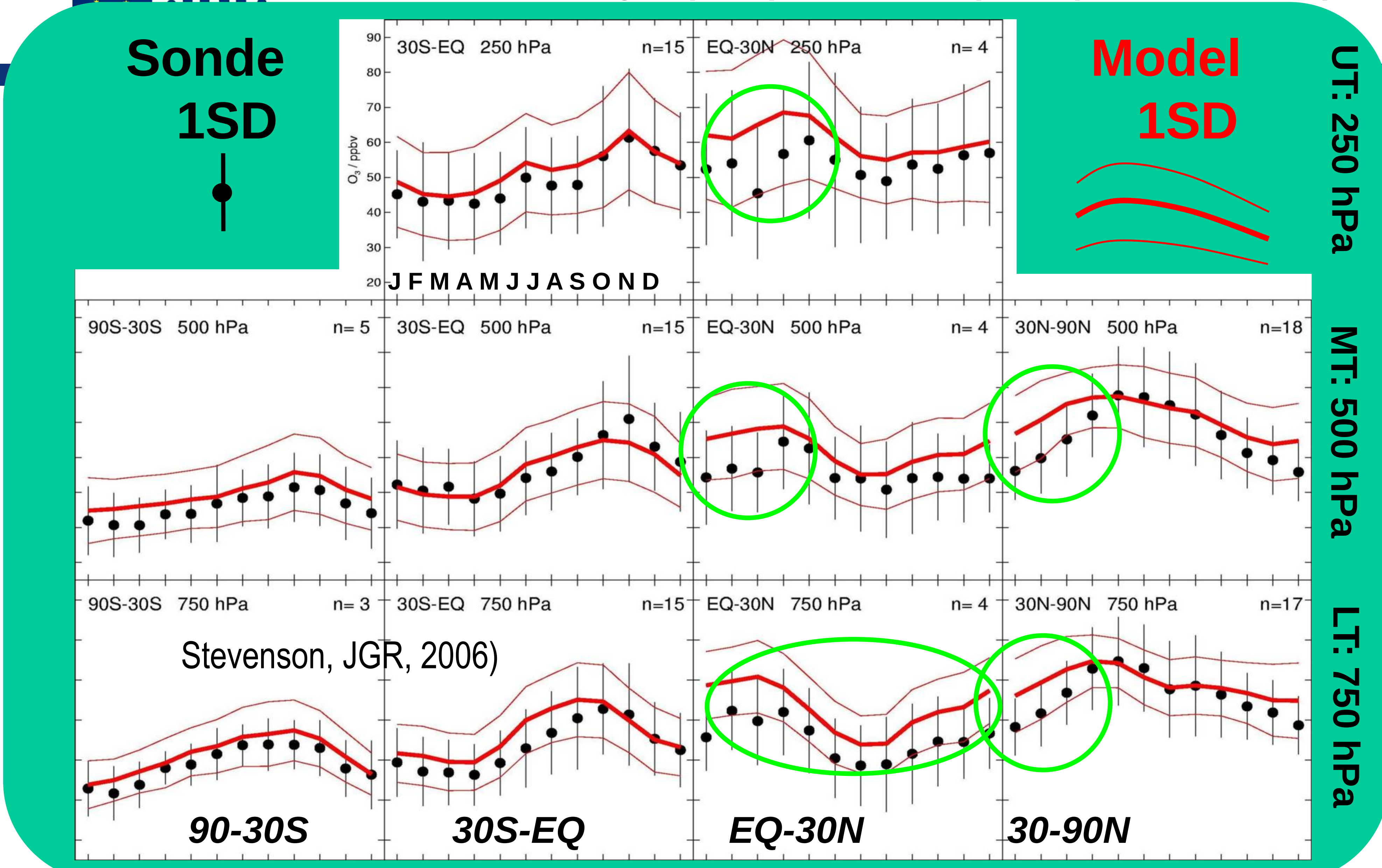
Comparison with satellite date:

NO2 and CH2O column (molec/cm2) (GOME;10:30 Local Time)

CO (MOPITT of CO columns)

All data on Oslo SRB server; no strict data format requirements.

Sonde data: Logan (1999) + SHADOZ (Thompson et al, 2003)



Ensemble mean model closely resembles ozone-sonde measurements

O3 air quality: questions

- How well do current global models represent surface ozone
- What does this mean for the most widely used ozone air quality indicators (human health+vegetation), and for their future development?
- What measurements should be used for comparison and how?
- Do models with higher resolution perform consistently better?

O3 Health Indicators

Index	Definition	Thresholds and effects
SOMO35 (nmol/mol.days)	$\sum_{i=1}^{n}$ [max_8 h_mean − 35]$_i$ for max_8 h_mean> 35 nmol/mol, where max_8h_mean is the daily maximum 8 h average ozone vmr in nmol/mol, *n* is the number of days in a year.	Threshold: No threshold defined
EU60 (days)	Number of days with maximum 8-h average ozone vmr exceeding 60 nmol/mol	Threshold: 25 days per year (during a three years period)
USEPA80 (days)	Number of days with maximum 8-h average ozone vmr exceeding 80 nmol/mol.	Threshold: the 3-year average of the 4th highest daily maximum at each location must not exceed 80 nmol/mol (equivalent to a maximum value of 3 days of exceedance per year)

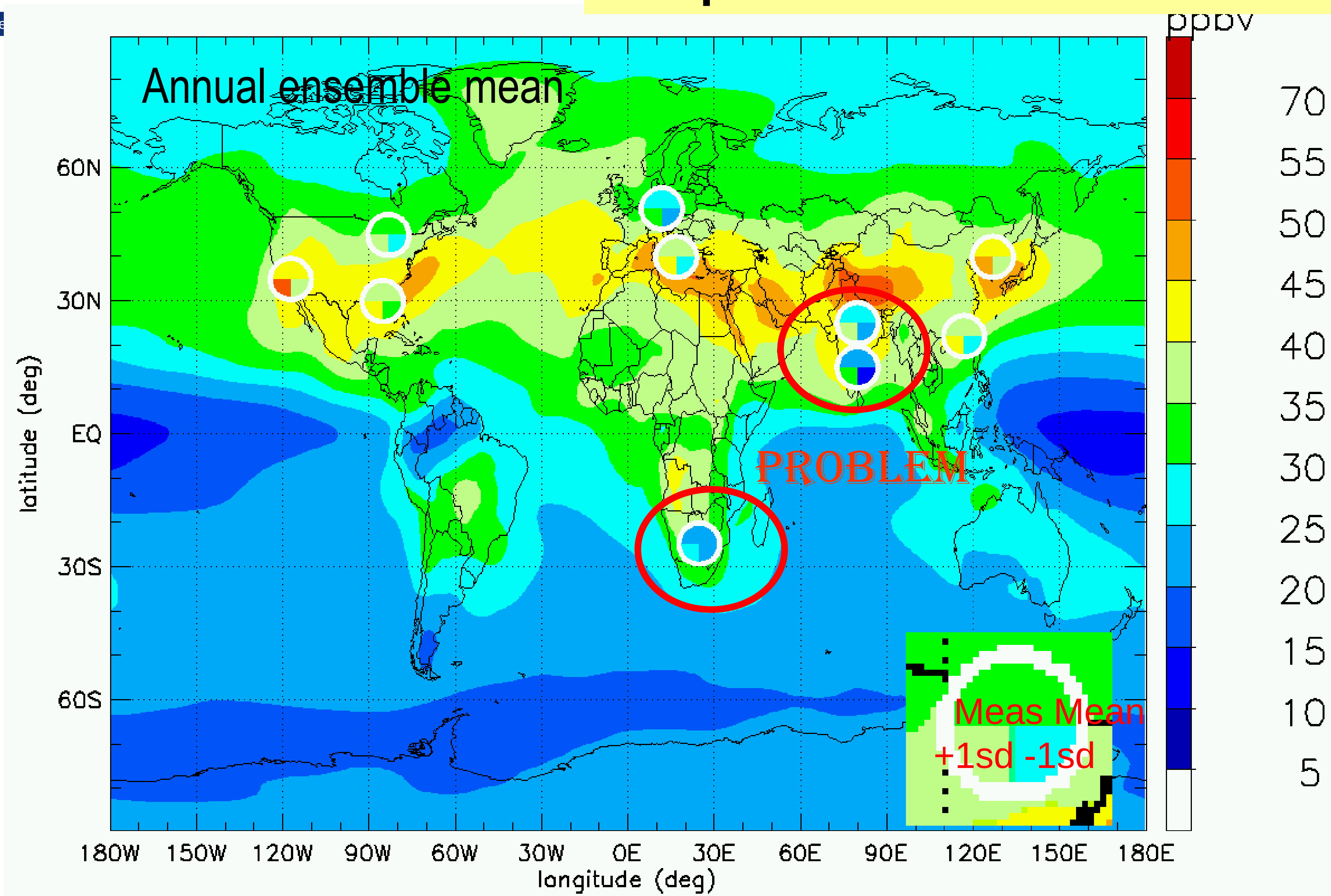
All indicators emphasize 'daytime' ozone (models might perform better)

O3 Vegetation Indicators

Vegetation index	Definition	Receptor
AOT40 (nmol/mol.hr)	Sum of hourly daylight (>50 W/m^2 PAR) ozone volume mixing ratio (vmr) above 40 nmol/mol: $\sum_{i=1}^{n} [CO_3 - 40]_i$ for CO_3>40 nmol/mol where CO_3 is the hourly ozone vmr in nmol/mol and n is the number of hours with CO_3>40 nmol/mol.	Agricultural crops: Accumulated over 3 consecutive months of the growing season. . Threshold: 3000 nmol/mol h European growing season: May to July
		Forest trees: Accumulated over 6 consecutive months of the growing season. Threshold: 5000 nmol/mol h European Growing season: April to September
SUM06 (nmol/mol.hr)	Sum of 24-hourly ozone vmr at or above 60 nmol/mol: $\sum_{i=1}^{n} [CO_3]_i$ for $CO_3 \geq 60$ nmol/mol where CO_3 is the hourly ozone vmr in nmol/mol and n is the number of hours with $CO_3 \geq 60$ nmol/mol.	Vegetation: Accumulated over 3 consecutive months of the growing season. Threshold: No threshold defined
W126 (nmol/mol h)	Weighted sum of 24-hourly ozone vmr: $\sum_{i=1}^{n} [CO_3]i * wi$ where $w_i = 1/(1+4403 * \exp(-0.126 * CO_{3i}))$ and CO_{3i} is the hourly ozone vmr in nmol/mol.	Vegetation: Accumulated over 3 consecutive months of the growing season. Threshold: No threshold defined

Indicators pertain to growing season: emphasize higher concentrations

Annual Average Surface ozone comparison with measurements



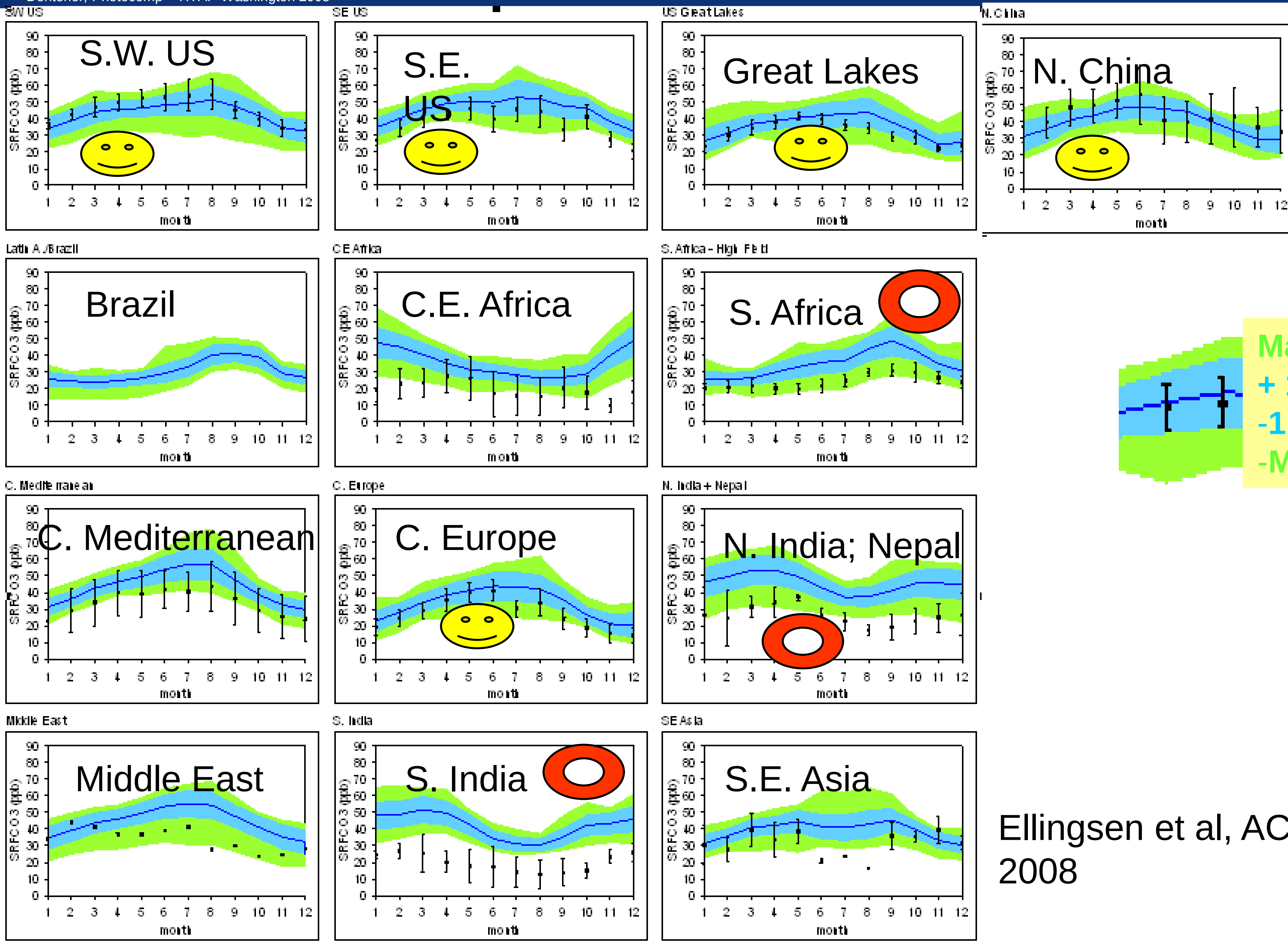
F. Dentener et al, ES&T, 2006

Regional analysis of clustered stations

Analysis of 14 aggregrated regions:

Region	Lat	Lon	# of stations	References
1. Southwestern U.S. LA regions	30 N–40 N	125 W–110 W	11	CASTNET [1)]
2. Southeastern U.S.	25 N–35 N	90 W–80 W	12	CASTNET [1)]
3. Great Lakes	40 N–50 N	95 W–75 W	13	CASTNET [1)]
4. Latin America/Brazil	25 S–15 S	50 W–30 W	N.a.	N.a.
5. Central-West Africa	5 N–15 N	5 W–15 E	3	Carmichael et al. (2003)
6. Southern Africa/High Field	30 S–20 S	20 E–35 E	6	Zunckel et al. (2004)
7. Central Mediterranean	35 N–45 N	5 E–30 E	21	EMEP, Airbase [2)]
8. Central Europe	48 N–54 N	7 E–17 E	101	EMEP, Airbase [2)]
9. Middle East	30 N–40 N	30 E–55 E	1	Carmichael et al. (2003)
10. North India + Nepal	20 N–30 N	70 E–90 E	6	Naja et al. (2003) Lal et al. (2000) Carmichael et al. (2003)
11. Southern India	10 N–20 N	75 E–85 E	4	Naja and Lal (2002) Debaje et al. (2003) Nair et al. (2002) Carmichael et al. (2003)
12. S.E. Asia (Guangzhou Hongkong)	20 N–35 N	110 E–125 E	3	Carmichael et al. (2003)
13. Northern China (Beijing)-Japan	35 N–45 N	110 E–145 E	8	WMO-WDCGG [3)] Akimoto and Pochanart (2005) Wang and Mauzerall (2004) Carmichael et al. (2003)
14. Australia	25 S–40 S	145 E–155 E	N.a.	N.a.

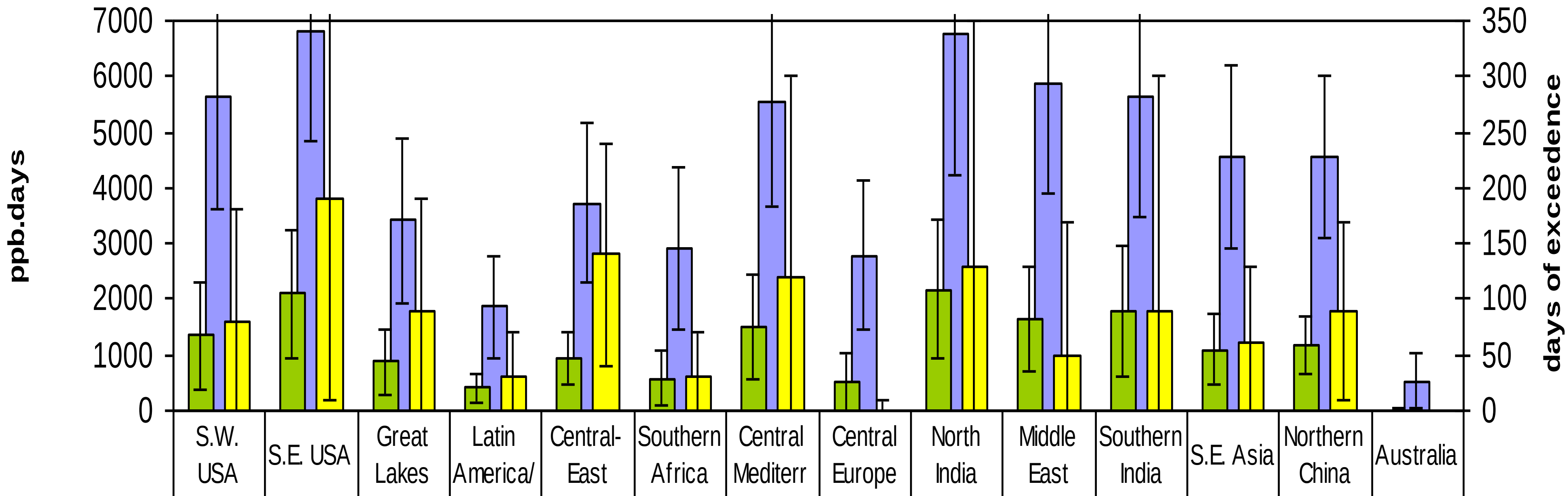
Monthly average Surface ozone comparison with measurements



Ellingsen et al, ACPD 2008

3 different metrics for O_3 exceedance: SOMO35; EU(60 ppbv); USEPA(80 ppbv)

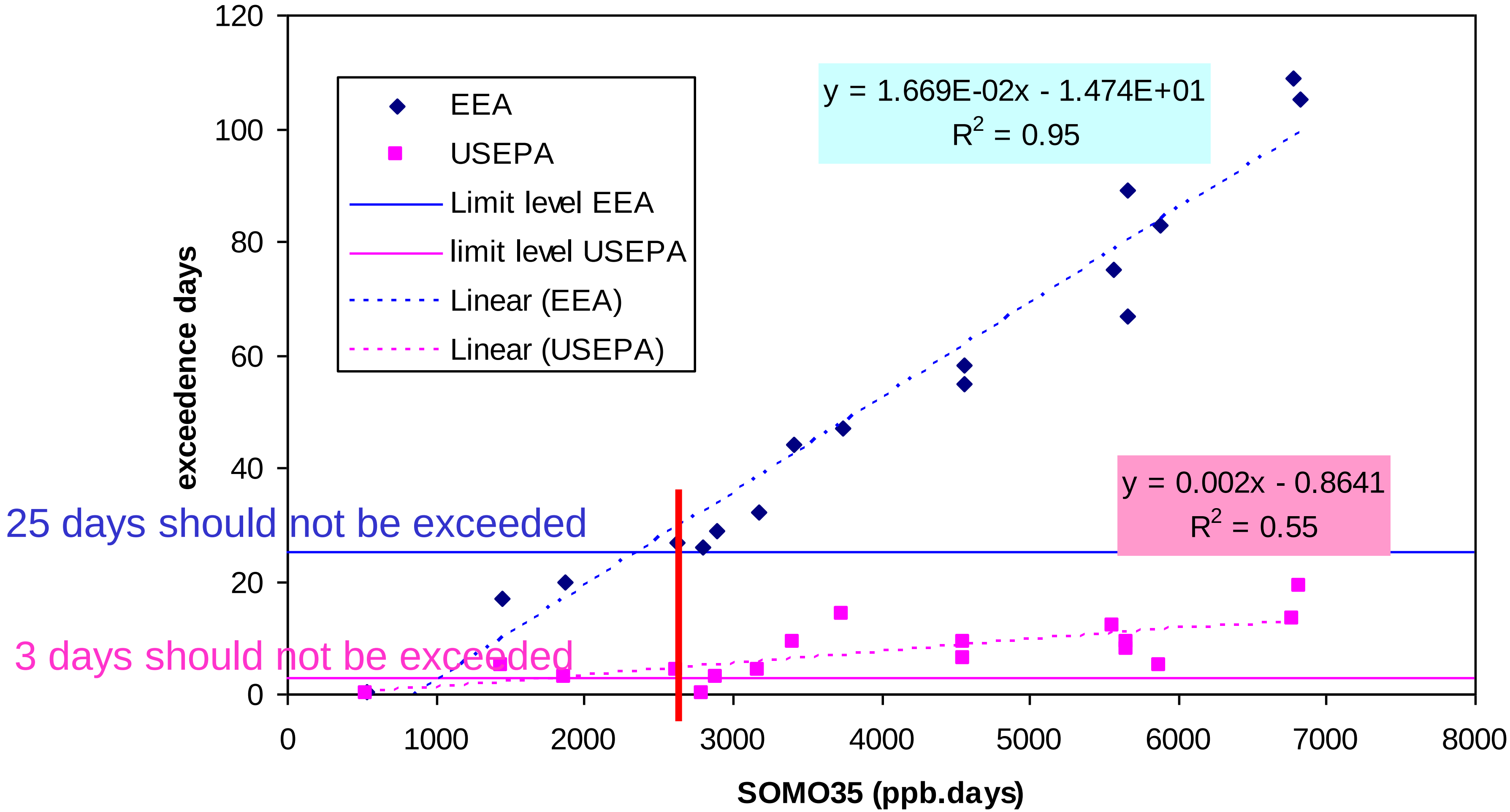
S1



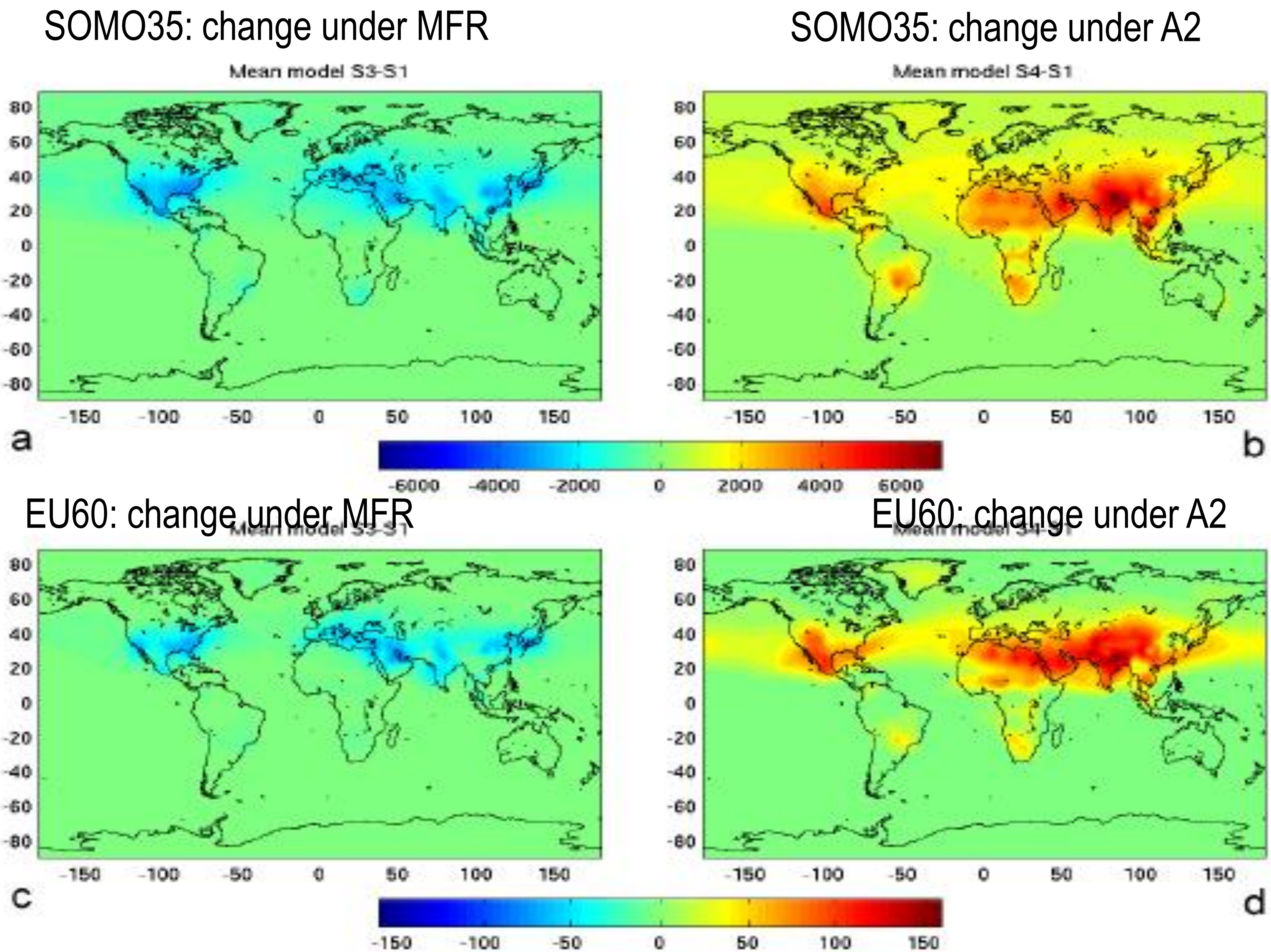
	S.W. USA	S.E. USA	Great Lakes	Latin America/	Central-East	Southern Africa	Central Mediterr	Central Europe	North India	Middle East	Southern India	S.E. Asia	Northern China	Australia
SOMO35	5654	6822	3412	1869	3733	2895	5559	2795	6780	5874	5656	4564	4559	540
EEA	67	105	44	20	47	29	75	26	109	83	89	55	58	0.6
USEPA *10	80	190	90	30	140	30	120	0	130	50	90	60	90	0

Ellingsen et al, ACPD, 2008

Statistical Relationship between SOMO35, European, and US EPA standards

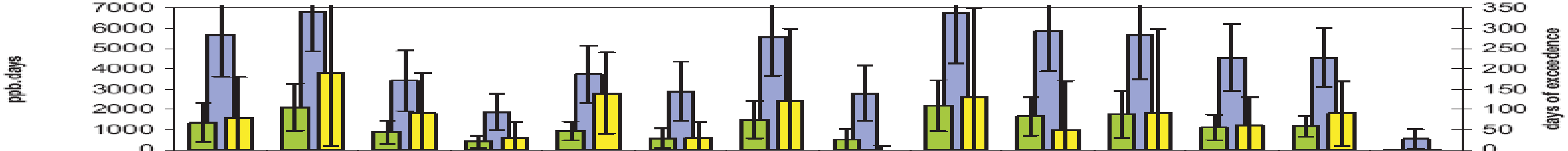


Ellingsen et al, ACPD, 2008



SOMO35: change under MFR
Mean model S3-S1
SOMO35: change under A2
Mean model S4-S1
a
b
-6000
-4000
-2000
0
2000
4000
6000
EU60: change under MFR
Mean model S3-S1
EU60: change under A2
Mean model S4-S1
c
d
-150
-100
-50
0
50
100
150

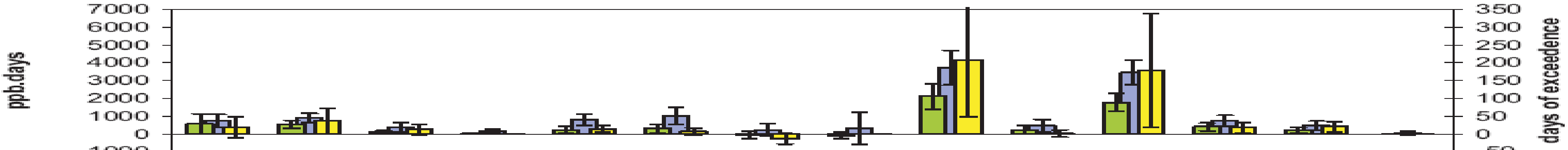
S1



	S.W. USA	S.E. USA	Great Lakes	Latin America/ Brazil	Central-East Africa	Southern Africa	Central Mediterranean	Central Europe	North India	Middle East	Southern India	S.E. Asia	Northern China	Australia
SOMO35	5654	6822	3412	1869	3733	2895	5559	2795	6780	5874	5656	4564	4559	540
EEA	67	105	44	20	47	29	75	26	109	83	89	55	58	0.6
USEPA *10	80	190	90	30	140	30	120	0	130	50	90	60	90	0

a

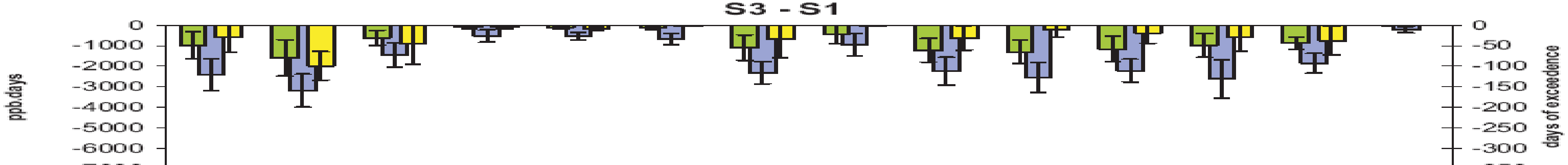
S2 - S1



	S.W. USA	S.E. USA	Great Lakes	Latin America/ Brazil	Central-East Africa	Southern Africa	Central Mediterranean	Central Europe	North India	Middle East	Southern India	S.E. Asia	Northern China	Australia
SOMO35	756	896	372	169	823	1018	234	341	3726	463	3453	743	479	50
EEA	28	27	6	2	12	15	-2	-4	106	12	89	20	11	0
USEPA *5	19	36	12	1	14	7	-13	-1	208	2	179	18	20	0

b

S3 - S1



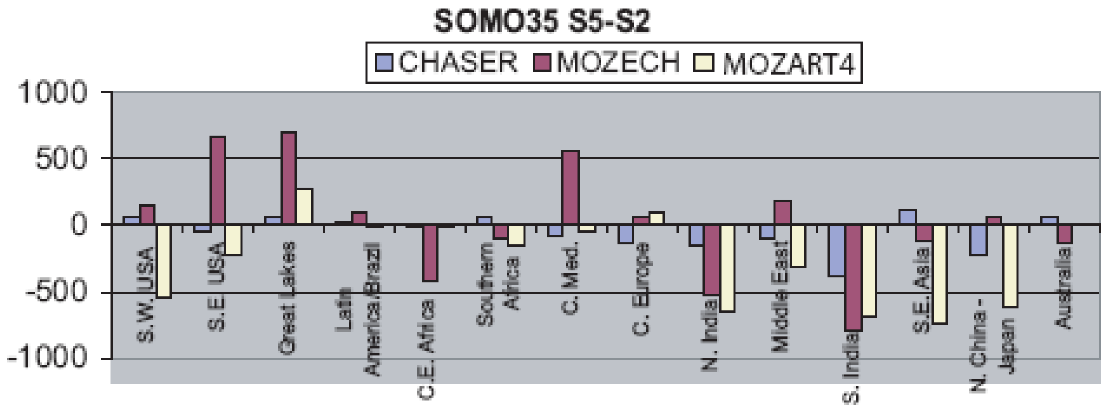
	S.W. USA	S.E. USA	Great Lakes	Latin America/ Brazil	Central-East Africa	Southern Africa	Central Mediterranean	Central Europe	North India	Middle East	Southern India	S.E. Asia	Northern China	Australia
SOMO35	-2394	-3183	-1464	-530	-542	-668	-2318	-935	-2239	-2549	-2214	-2612	-1854	-217
EEA	-49	-80	-31	-5	-6	-7	-55	-23	-61	-65	-58	-49	-44	0
USEPA *5	-30	-99	-45	-4	-9	-3	-35	-2	-31	-10	-19	-28	-38	0

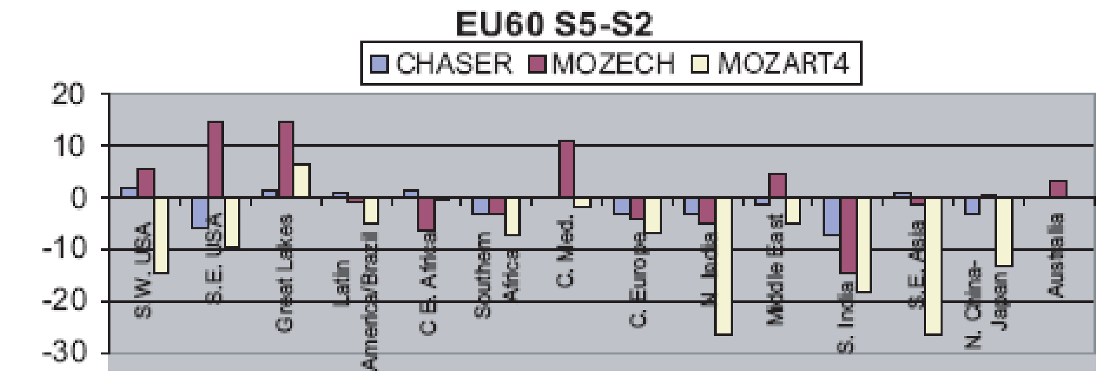
c

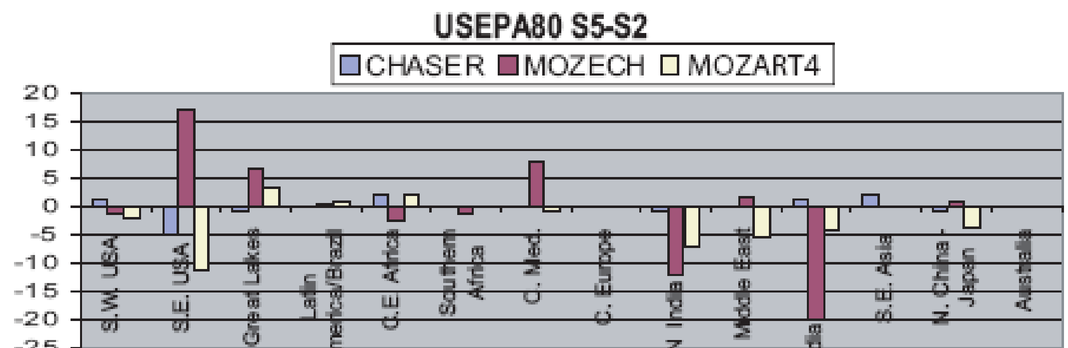
S4 - S1

	S.W. USA	S.E. USA	Great Lakes	Latin America/ Brazil	Central-East Africa	Southern Africa	Central Mediterranean	Central Europe	North India	Middle East	Southern India	S.E. Asia	Northern China	Australia
SOMO35	2480	2612	1403	2371	3130	2596	2136	1133	6017	3103	4737	3126	2048	410
EEA	60	59	58	60	63	62	64	64	68	57	51	40	32	27
USEPA *5	100	145	55	25	55	25	55	20	450	135	305	195	100	0

d


SOMO35 S5-S2
CHASER
MOZECH
MOZART4
1000
500
0
-500
-1000
S.W. USA
S.E. USA
Great Lakes
Latin America/Brazil
C.E. Africa
Southern Africa
C. Med.
C. Europe
N. India
Middle East
S. India
S.E. Asia
N. China - Japan
Australia


EU60 S5-S2
CHASER
MOZECH
MOZART4
20
10
0
-10
-20
-30
S.W. USA
S.E. USA
Great Lakes
Latin America/Brazil
C.E. Africa
Southern Africa
C. Med.
C. Europe
N. India
Middle East
S. India
S.E. Asia
N. China-Japan
Australia


USEPA80 S5-S2
CHASER
MOZECH
MOZART4
20
15
10
5
0
-5
-10
-15
-20
S.W. USA
S.E. USA
Great Lakes
C.E. Africa
Southern Africa
C. Med.
C. Europe
Middle East
S.E. Asia
N. China - Japan
Australia

Status of ‘Ellingsen’ ACPD 2008 paper:

2 reviews: one moderately critical and one much more critical.

Main criticisms:

- Can global models be used for air quality assessment, if at a number of places there is such a discrepancy with measurements? (less focus on scenarios)
- Discussion of reasons for disagreements is rather qualitative but does not offer a way forward.
- Analysis of models results and differences could be more rigorous….
- This represent a practical problem

Model measurement discrepancies are caused by:

"Inaccurate description of emissions, meteorological and chemical processes in models"

- Emission inventories and technology levels are based on information from Europe and North America, the uncertainties are much larger in other continents, e.g. in Asia differences of up to 40% are found in NOx between the inventory used in photocomp. Satellite images indicate a factor of two!
- Most models are driven by meteorological parent models that are better tested andconstrained in middle latitudes than in tropical regions. Also the effect of degradation of the driving meteorology into lower resolution meteorology typically used in CTMs may be important. Turbulent and convective mixing play a relatively important role for mixing of air pollution in the tropics but these mixing parameterizations have been hardly tested in low latitudes and their impacts on surface ozone are not easy to predict.
- What resolution is needed?
- What chemistry is needed?

Model measurement discrepancies are caused by:

Which measurements and how to use them?

- •Only reasonable (sufficient?) amount of measurements in Europe and US.
- •Other regions have not enough stations for good statistics
- •Quality control is not clear (especially for the obs used in South Asia)
- •The non-representativeness of measurements for the large-scale model gridboxes may be important.
- •Measurements are often performed at sfc level (or 5-10 m). Models generally did not provide this info.
- •Would be good to have Ox (NO2+O3) from models and measurements

What is next?

Needed to have more realistic simulation capacity of global models for ozone airquality

- Better analysis of model –measurement O3 frequencies
  identify where/when where models go wrong.
- Better resolutions would probably help
- Sub-grid scaling of model results could take into account:
  high resolution emission information
  vertical distribution