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Global modelling of ozone production and effects on agriculture and health

Rita Van Dingenen (JRC)
Frank Dentener (JRC)
Frank Raes (JRC)
John van Aardenne (JRC)
Markus Amann (IIASA)

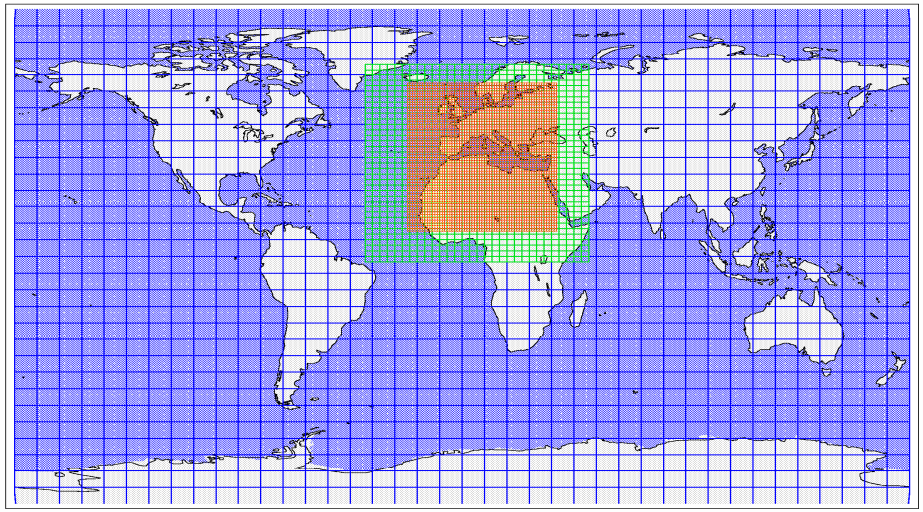
Institute for Environment and Sustainability

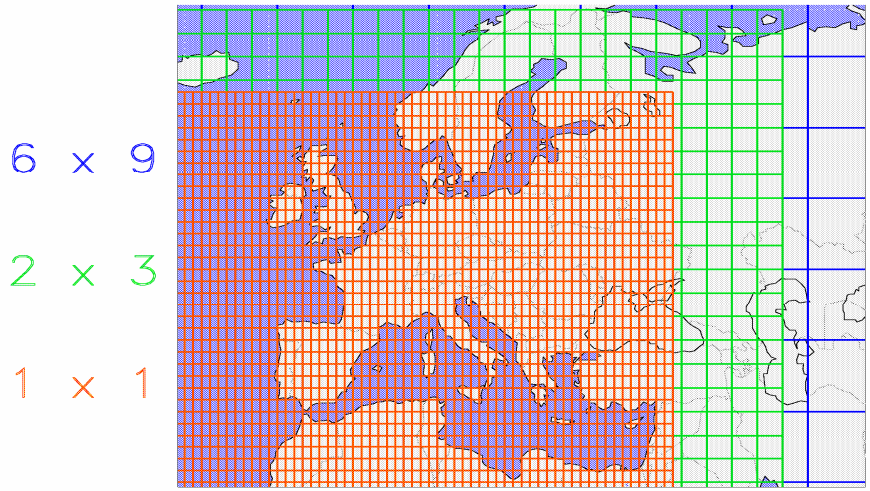
Presentation outline

1. Tools, methodology, boundaries
2. Ozone metrics and damage functions
3. Validation of modelled ozone levels
4. Global ozone impact on crop yield losses
5. Ozone impact on human health (mortality)
6. Conclusions and outlook

1a. Global Model TM5

- Global chemical transport model (TM5) for global assessment of air quality and its impacts (Frank Dentener)





- 1°x1° zooming capacity
- off-line meteorology
- meteo year 2000 ECMWF
- no climate change 2030
- global hourly surface ozone
- dry deposition parametrisation (big leaf concept, stomatal flux, no modifying factors)

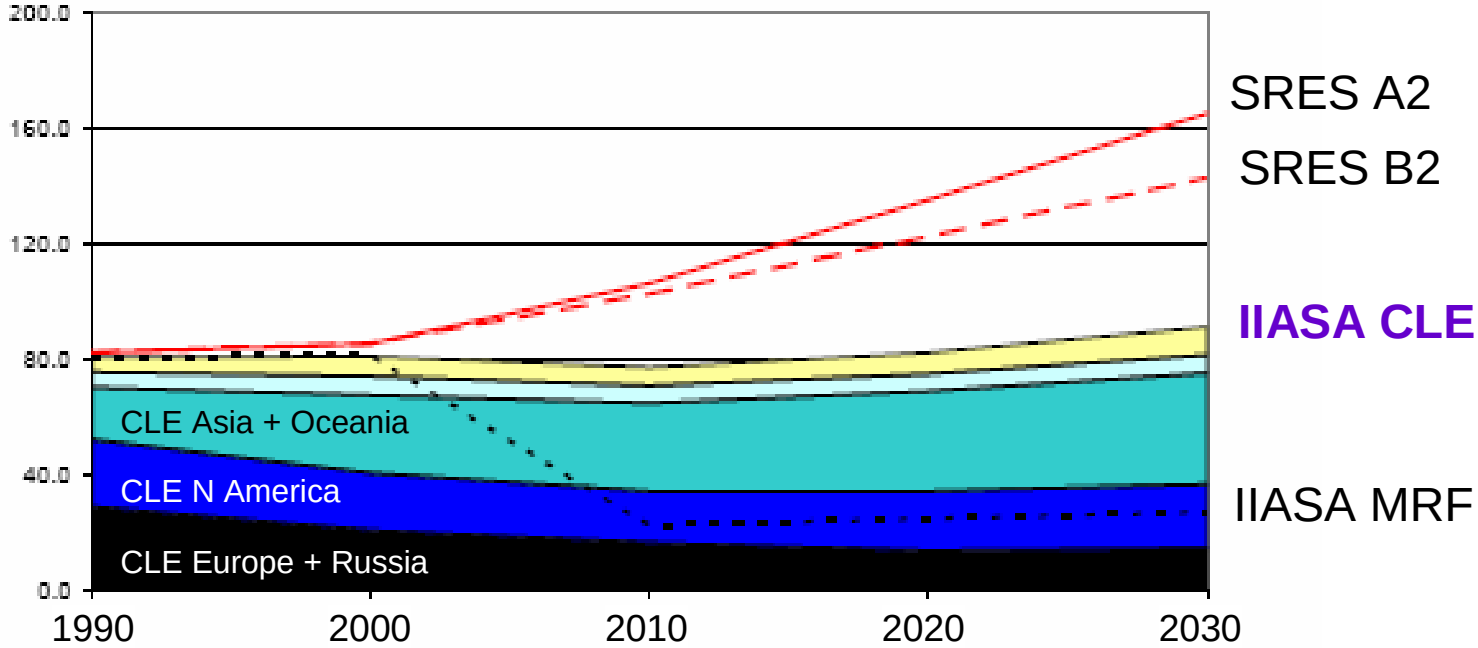
1b. Emissions - base year and projection

- **Run S1**
  - Base year: 2000
  - Emissions: EDGAR 3.2 (gridded 1°x1°)
- **Run S2**
  - Year 2030 (meteorology yr 2000)
  - Emissions by IIASA, gridded with EDGAR
  - CLE scenario = implemented current air quality legislation

1b. Emission scenario 2030

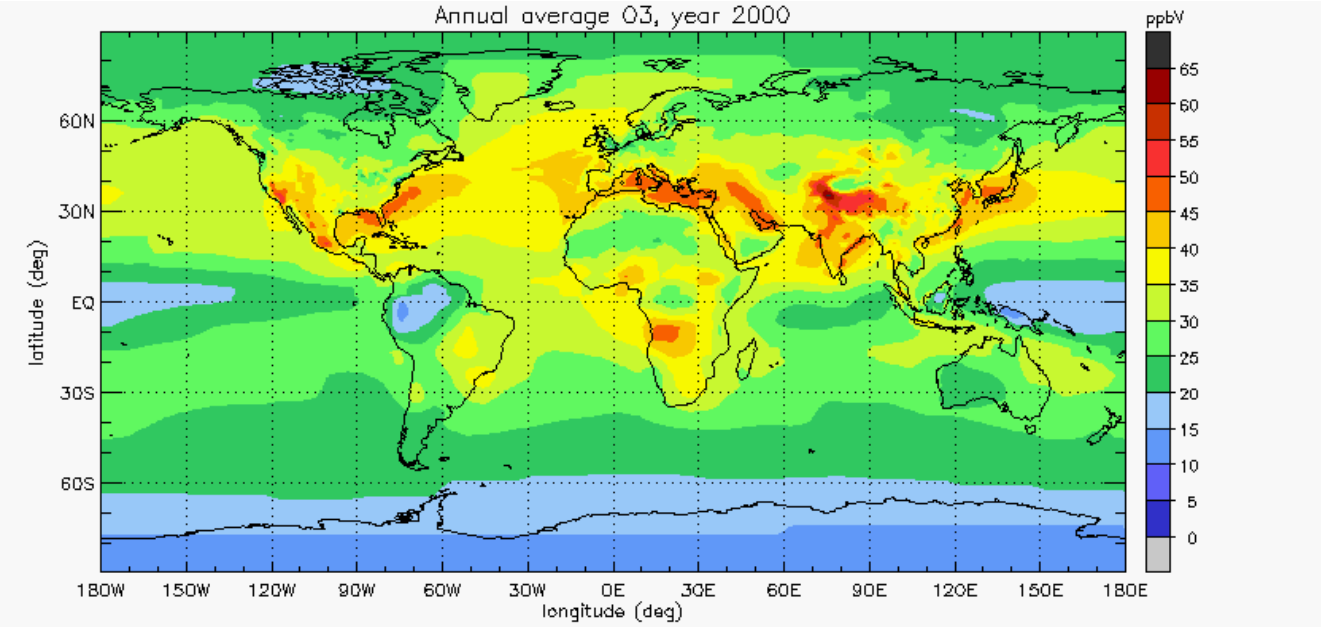
CLE emission scenario

Projected anthropogenic emissions NOx (Tg NO_2 y^{-1})

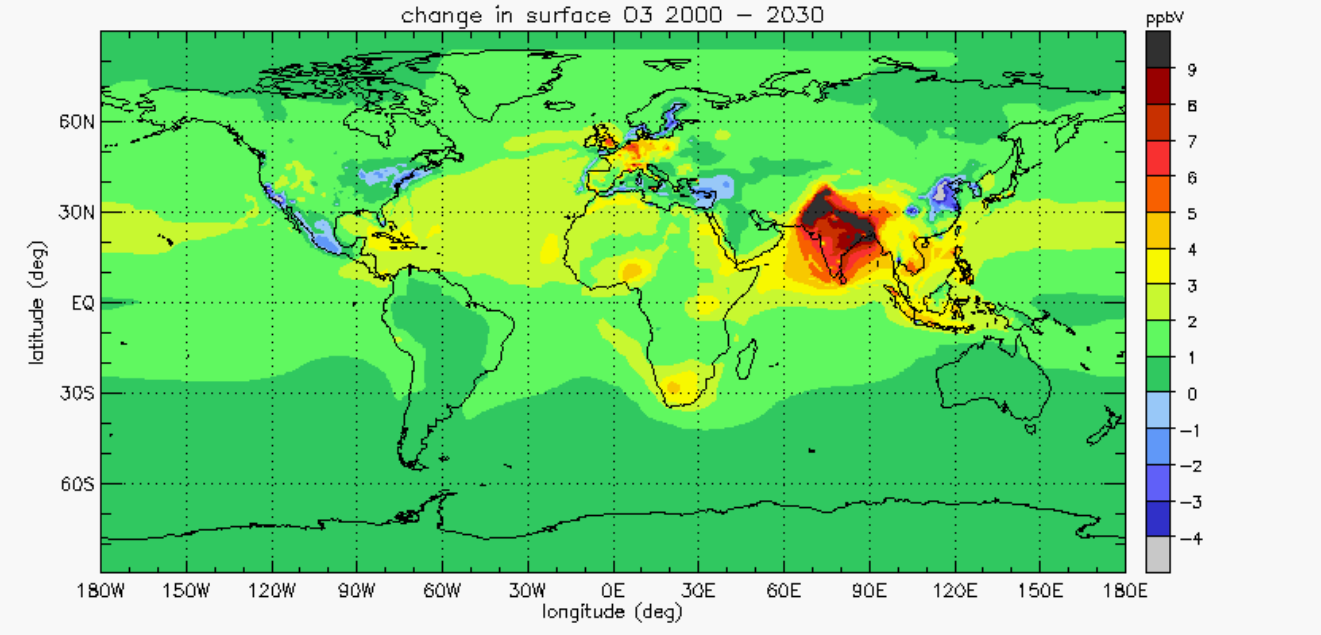


1c. TM5 ozone 2000 and 2030 CLE

TM5 Year 2000 averaged surface ozone

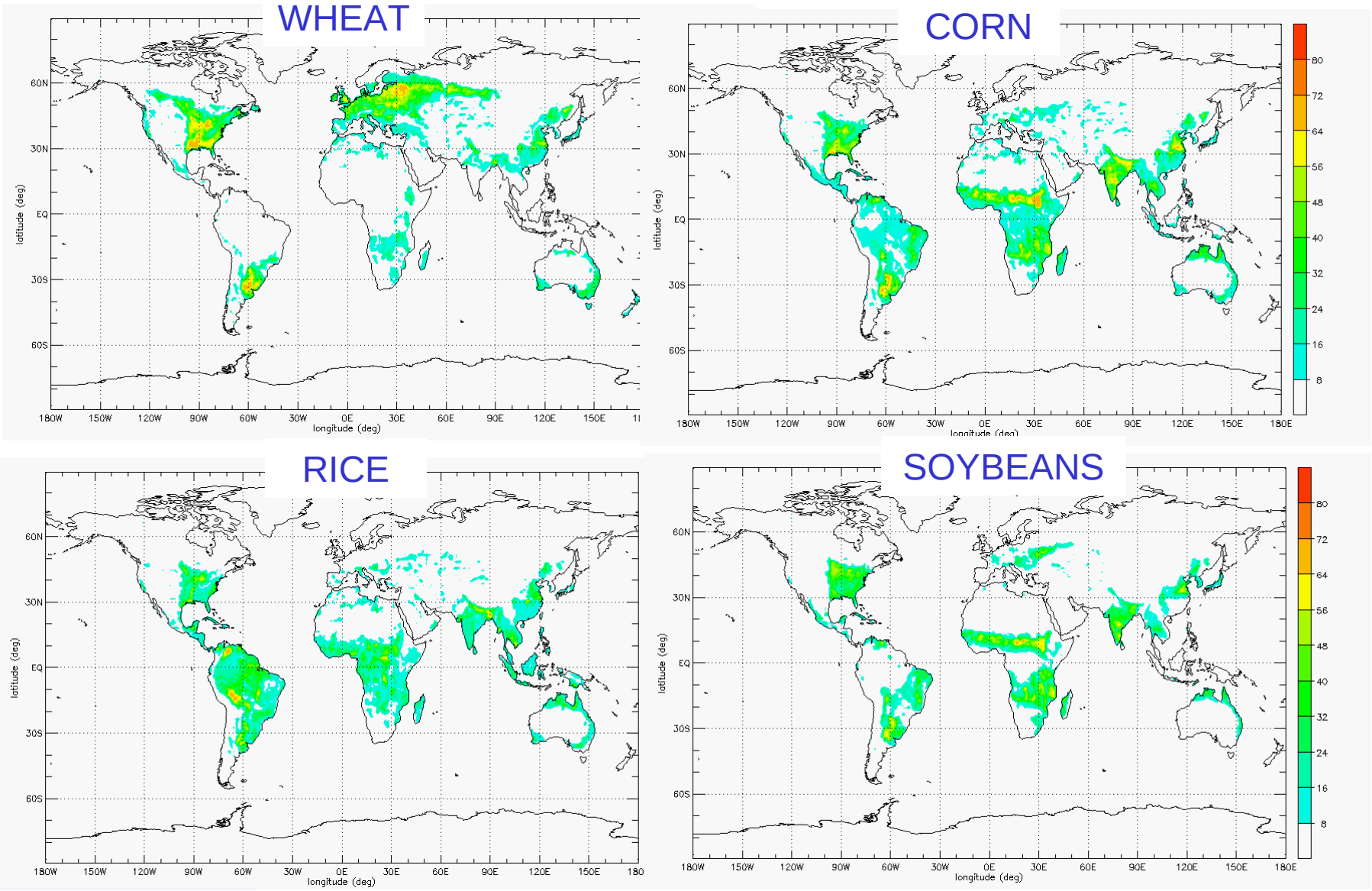


Change in surface ozone 2000 – 2030 (CLE)



1d. Crops and crop distribution

Suitability index for crop cultivation
(FAO/IIASA GAEZ project)



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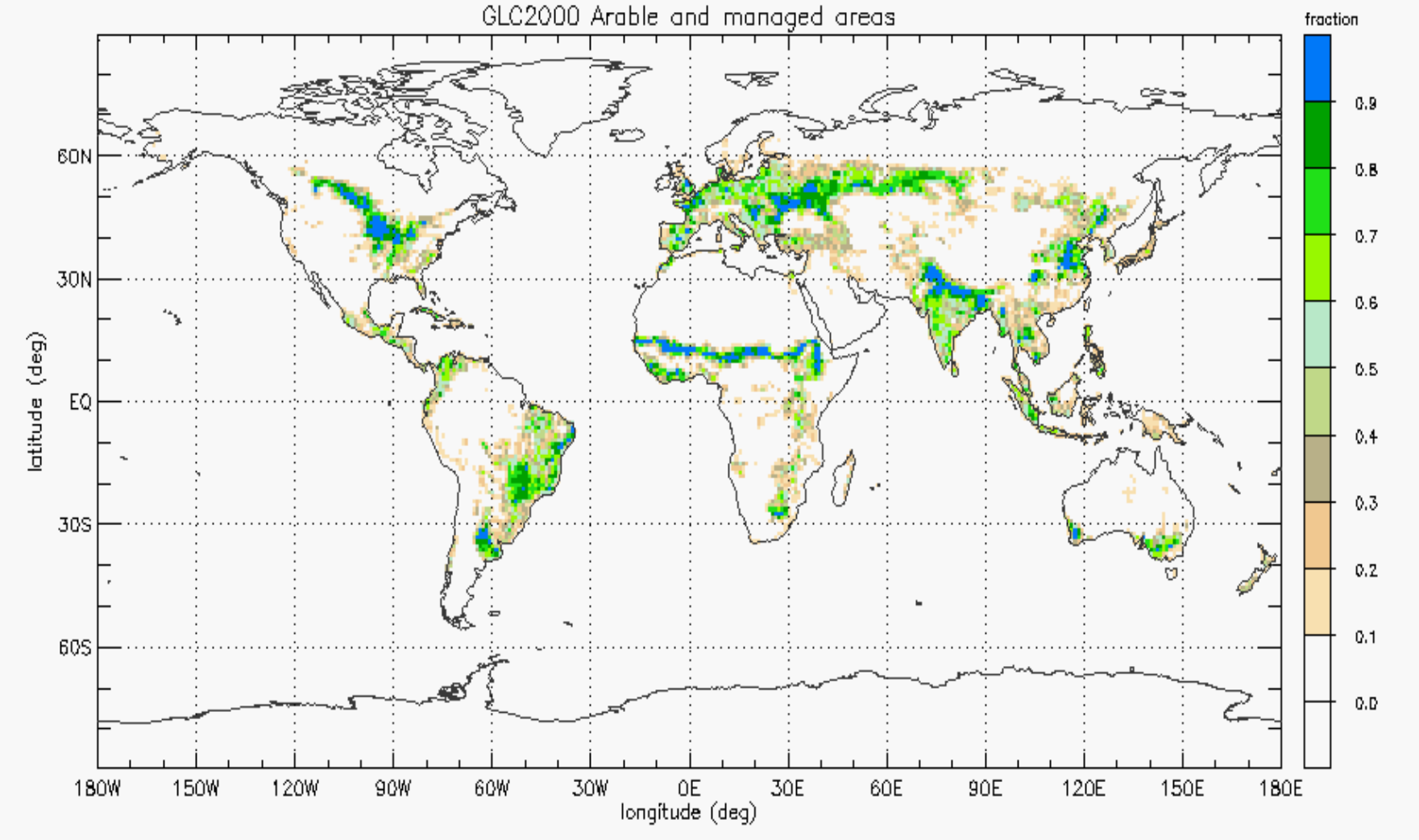
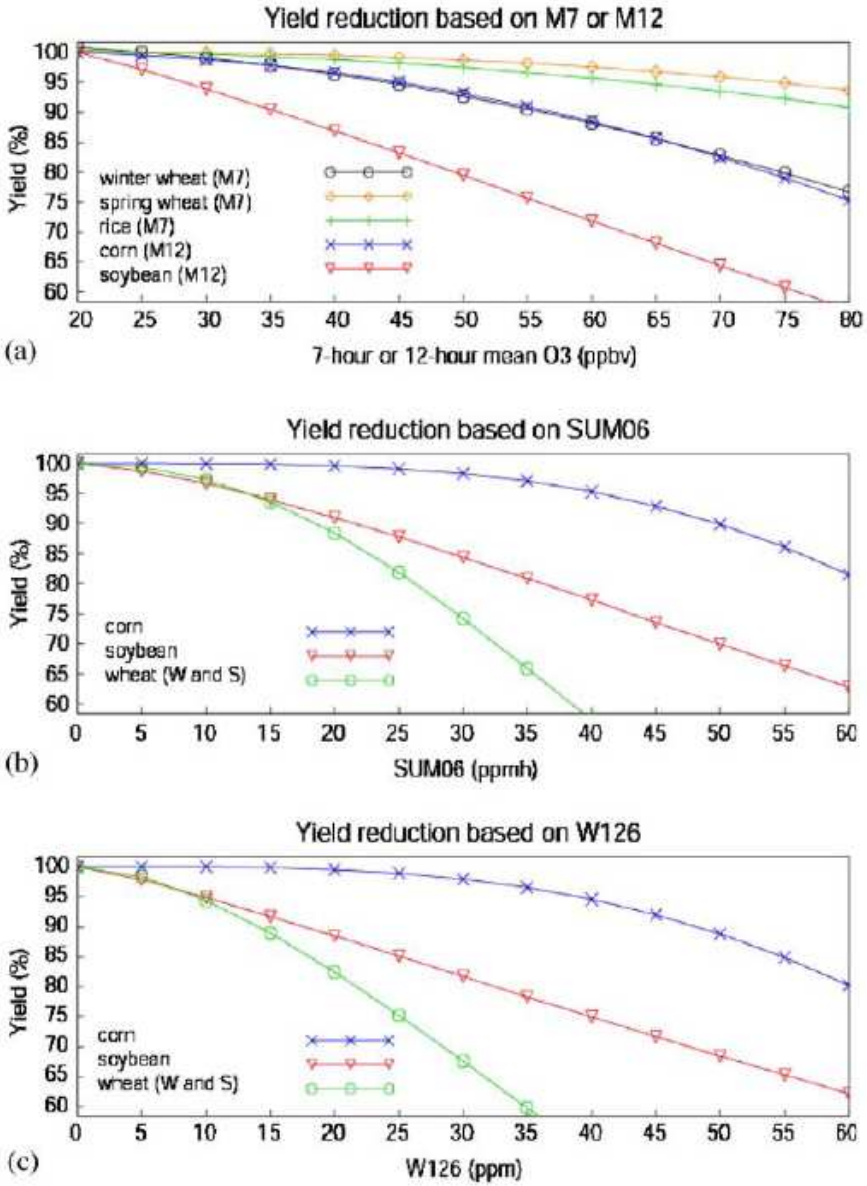


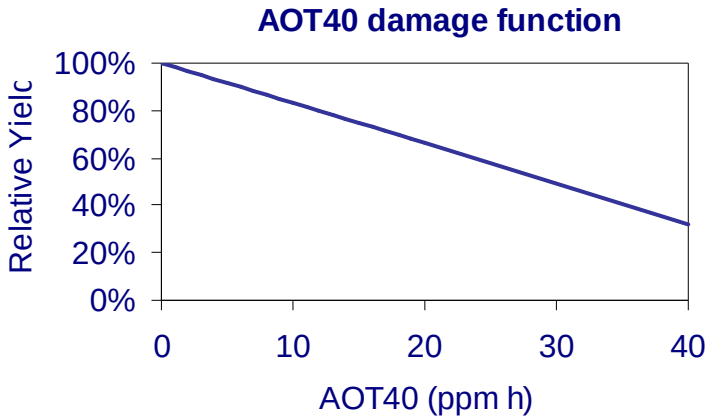
2. Ozone metrics evaluated

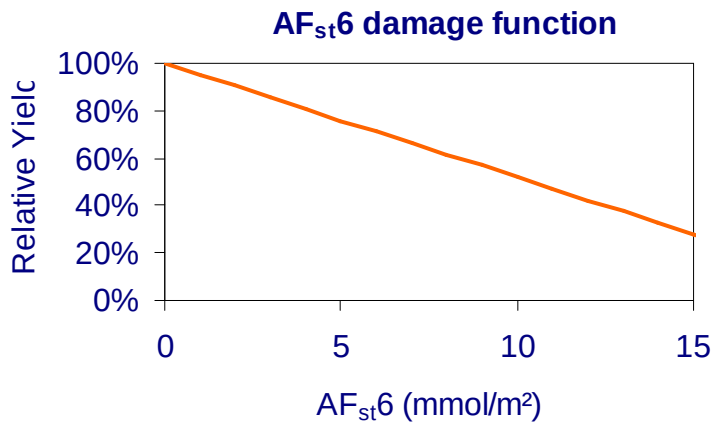
Crops	M7	M12	SUM06	W126	AOT40	AFst6
Rice	➡					
Corn		➡	➡	➡		
Soybeans		➡	➡	➡		
Wheat	➡		➡	➡	➡	➡
Type	conc. average		accumulated conc. above threshold			accum. stomatal flux
damage function	Weibull				linear	

Health	SOMO35

2. Damage curves







Wang and Mauzerall, 2004

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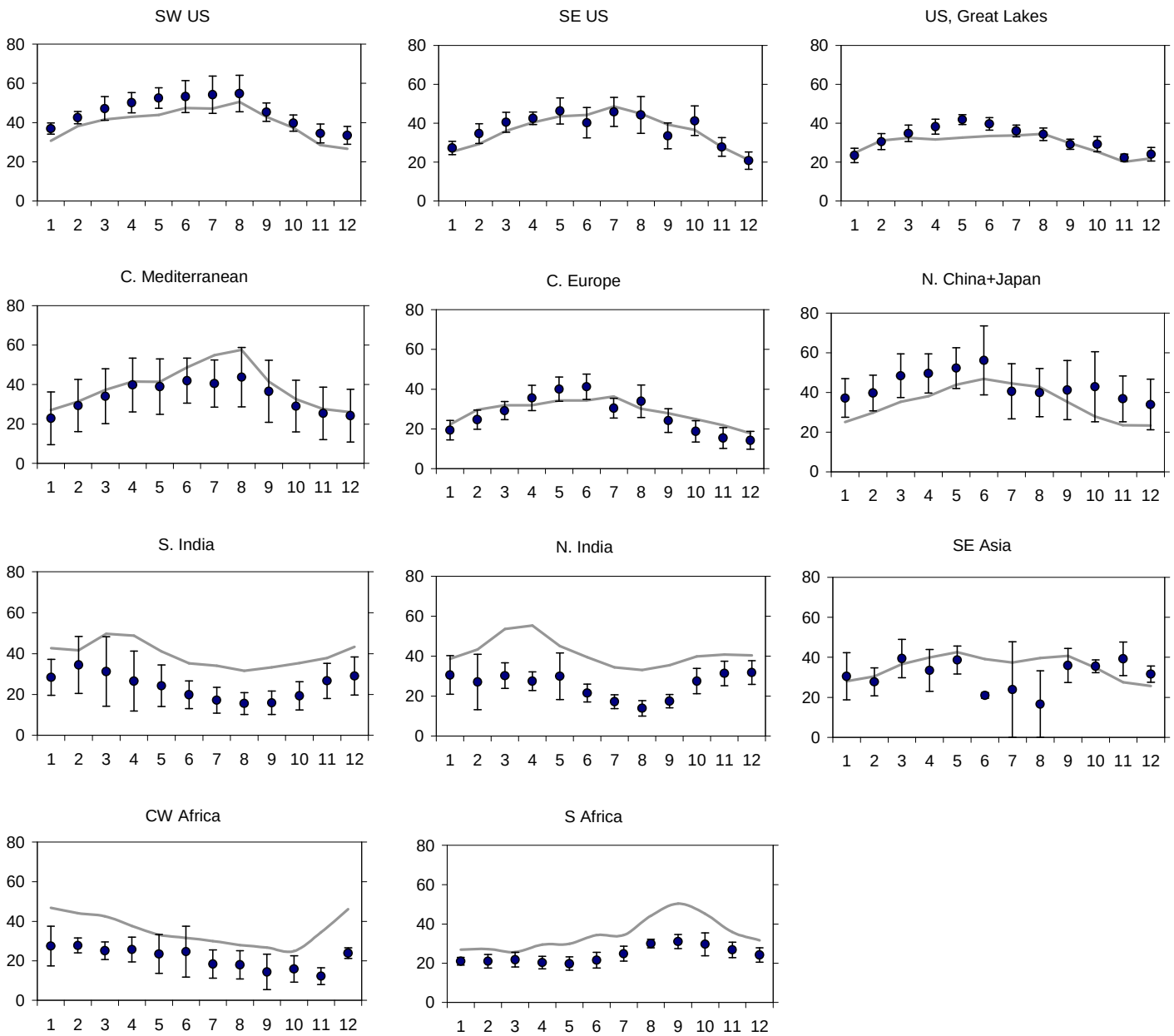
2. Ozone metrics: stomatal flux approach

- Availability of meteorology → evaluation of stomatal O_3 flux and associated damage function
- Following approach ICP Mapping manual + Simpson et al. (2007), Tuovinen et al. (2007), Pleijel et al. (2007)
- Includes effect of
  - Temperature
  - Light
  - Phenology (based on accumulated temperature)
  - Vapour pressure deficit (direct and accumulated)
  - Ozone senescence
- Not included: soil water potential

3. Model validation TM5: Monthly Means



3. Model validation: ozone metrics

	EUR	US	JAPAN	CHINA	INDIA
	AOT40				
R_g	**0.69**	**0.92**	**0.77**		
σ_g	3.04	3.08	2.40		
$(\sigma_g)^2$	9.25	9.48	5.75		
	W126				
R_g	**1.16**	**1.21**	**1.11**		
σ_g	2.87	3.44	2.56		
$(\sigma_g)^2$	8.26	11.84	6.55		
	SUM06				
R_g	**0.59**	**0.83**	**0.69**		
σ_g	1.95	2.86	2.54		
$(\sigma_g)^2$	3.82	8.18	6.43		
	M7			***M24***	
R_g	**1.07**	**1.19**	**1.24**	**0.94**	**2.04**
σ_g	1.32	1.44	1.31	1.38	1.43
$(\sigma_g)^2$	1.73	2.07	1.72	1.9	2.0

R_g = mean ratio monthly modelled/measured

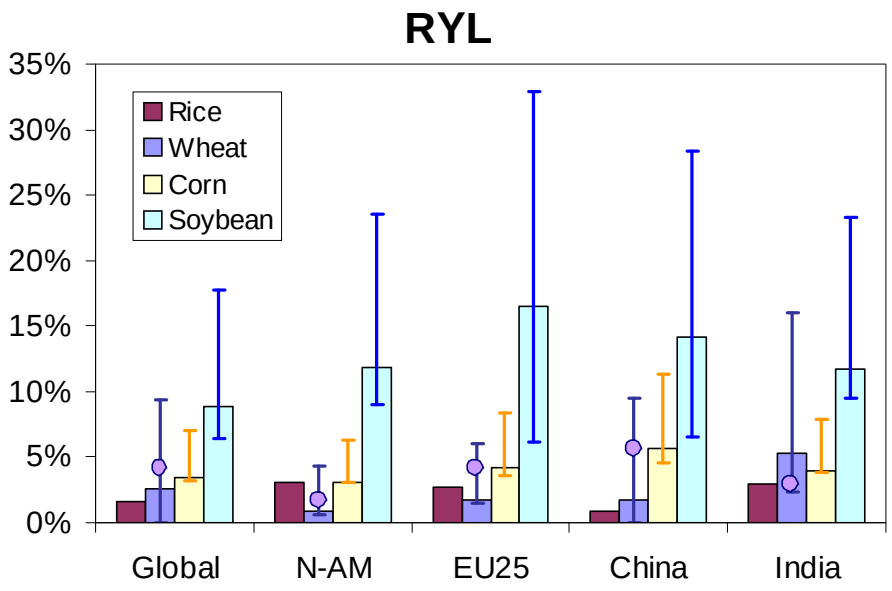
68% of the cases within a factor σ_g

95% of the cases within a factor $(\sigma_g)^2$

4. Results: Regional Relative Yield Losses 4 crops

Based on M7 and M12

	2000					2030, CLE				
	Global	N-AM	EU25	China	India	Global	N-AM	EU25	China	India
Wheat	2.5%	0.9%	1.7%	1.7%	5.3%	3.5%	0.8%	2.2%	1.4%	8.9%
Rice	1.6%	3.1%	2.7%	0.9%	2.9%	2.3%	3.1%	2.5%	1.0%	4.3%
Corn	3.5%	3.1%	4.2%	5.6%	3.9%	3.7%	3.3%	4.1%	5.3%	7.7%
Soybean	8.9%	11.8%	16.5%	14.2%	11.7%	9.5%	12.3%	15.5%	14.5%	18.6%

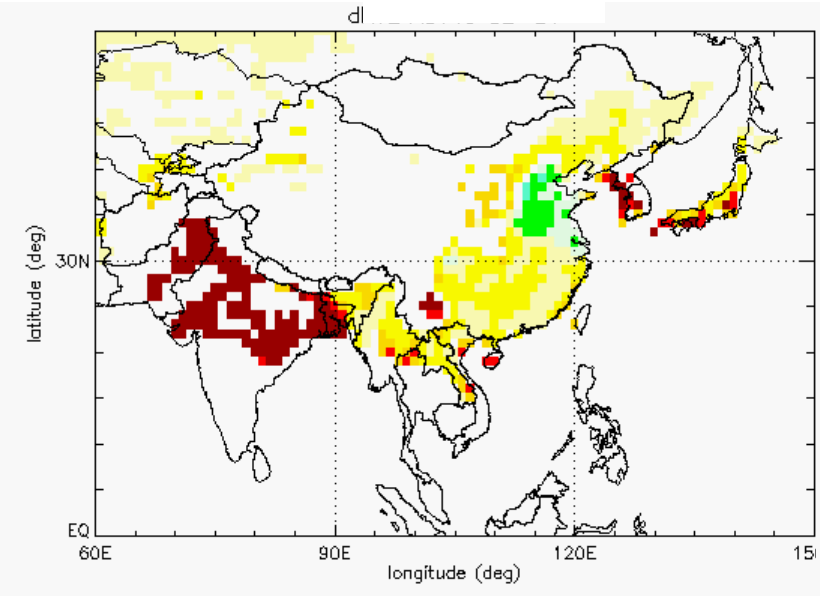


Error bars: range of all metrics
Dots (wheat): AFst6

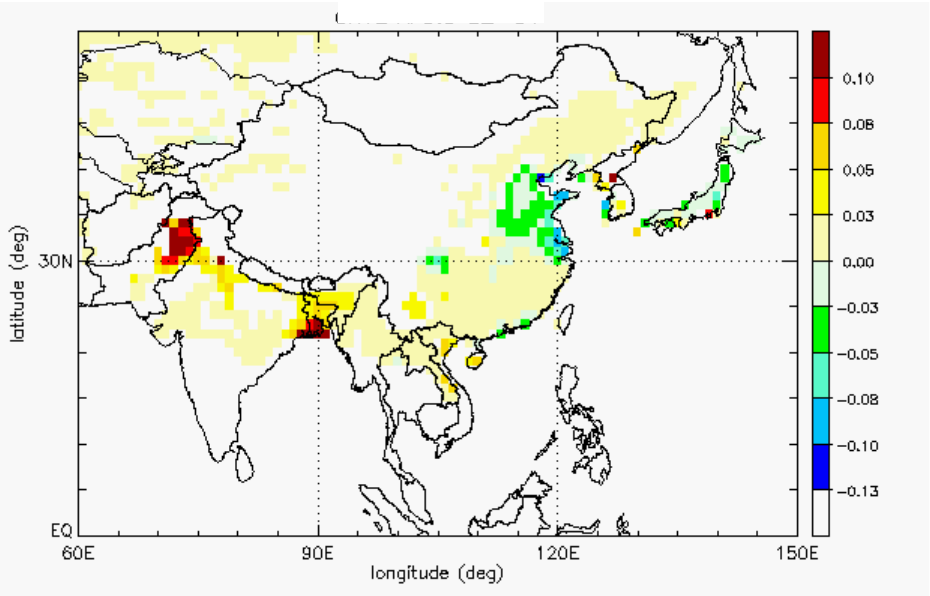
4. Results: relative yield losses

Change in relative yield loss wheat, Asia

AOT40



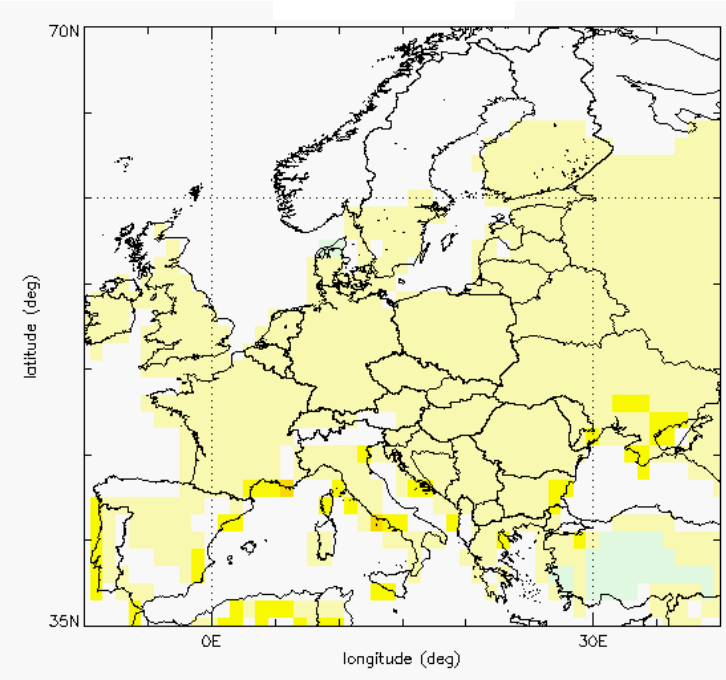
AFst6



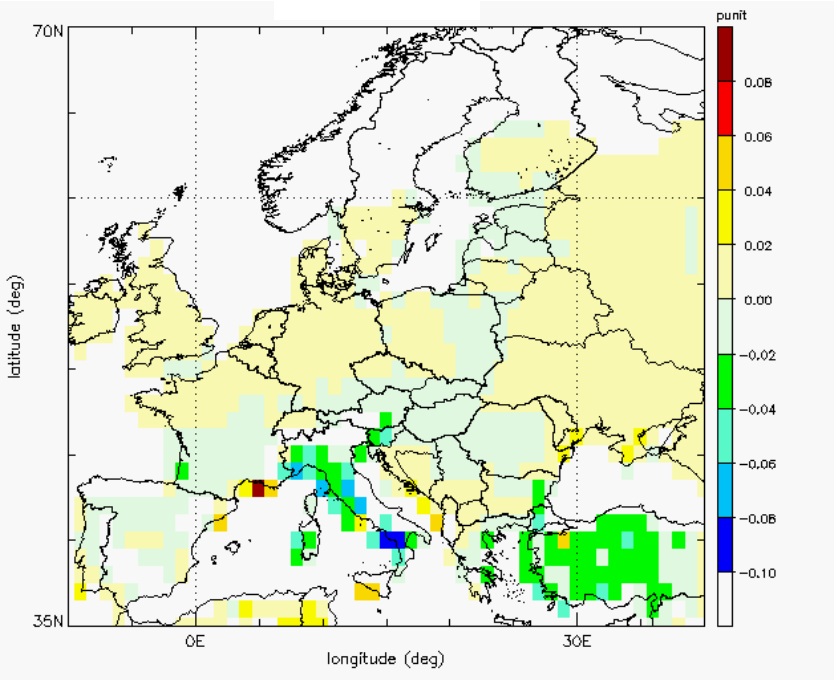
4. Results: relative yield losses

Change in relative yield loss wheat, Europe

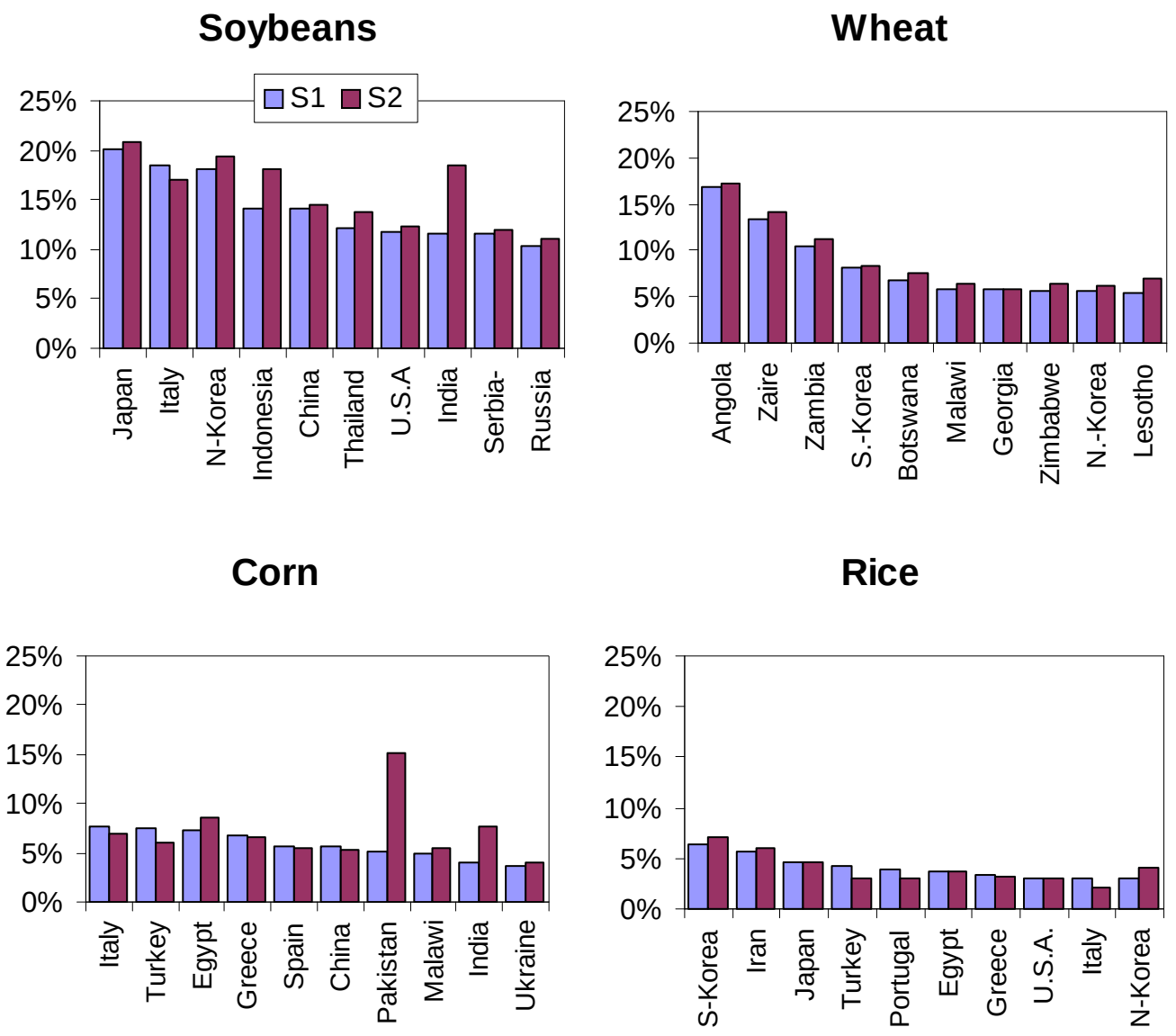
AOT40



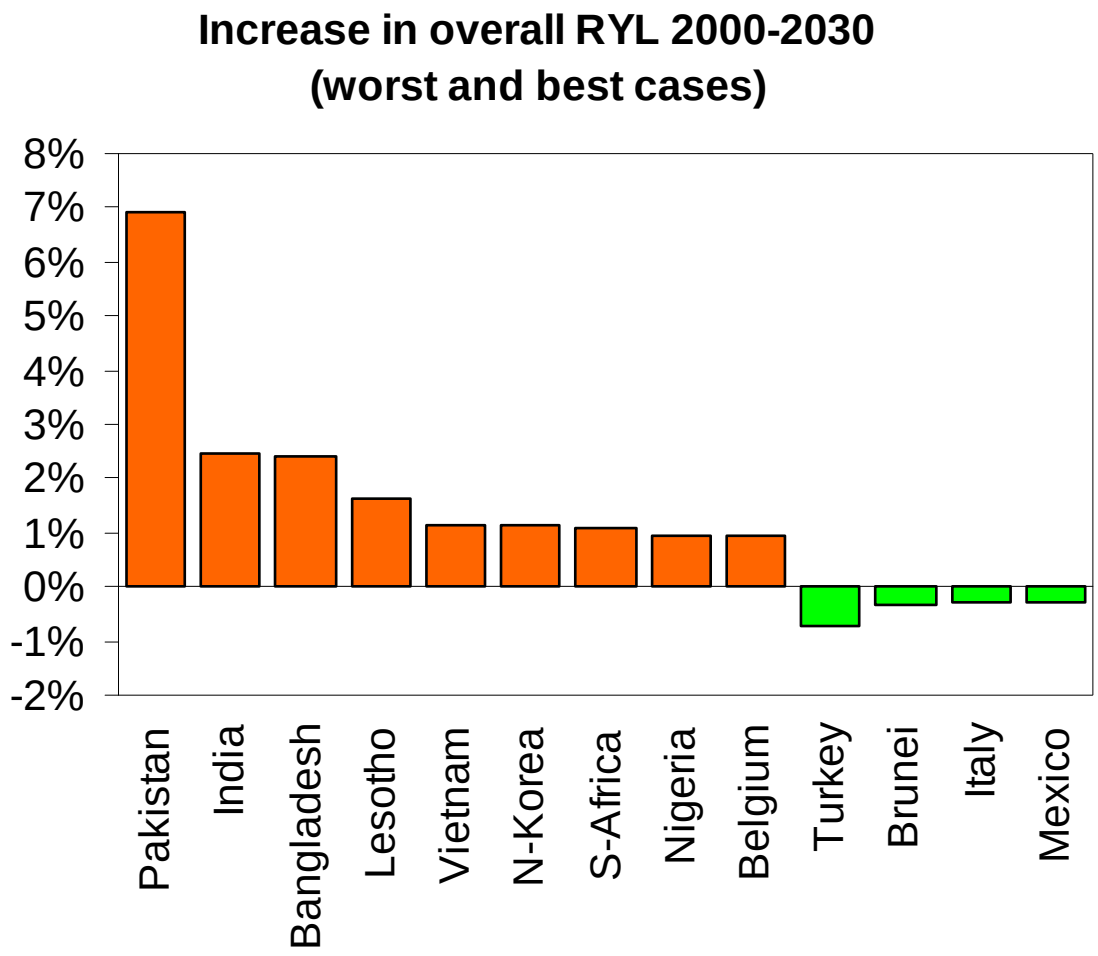
AFst6



4. Results: Relative Yield Loss, individual countries



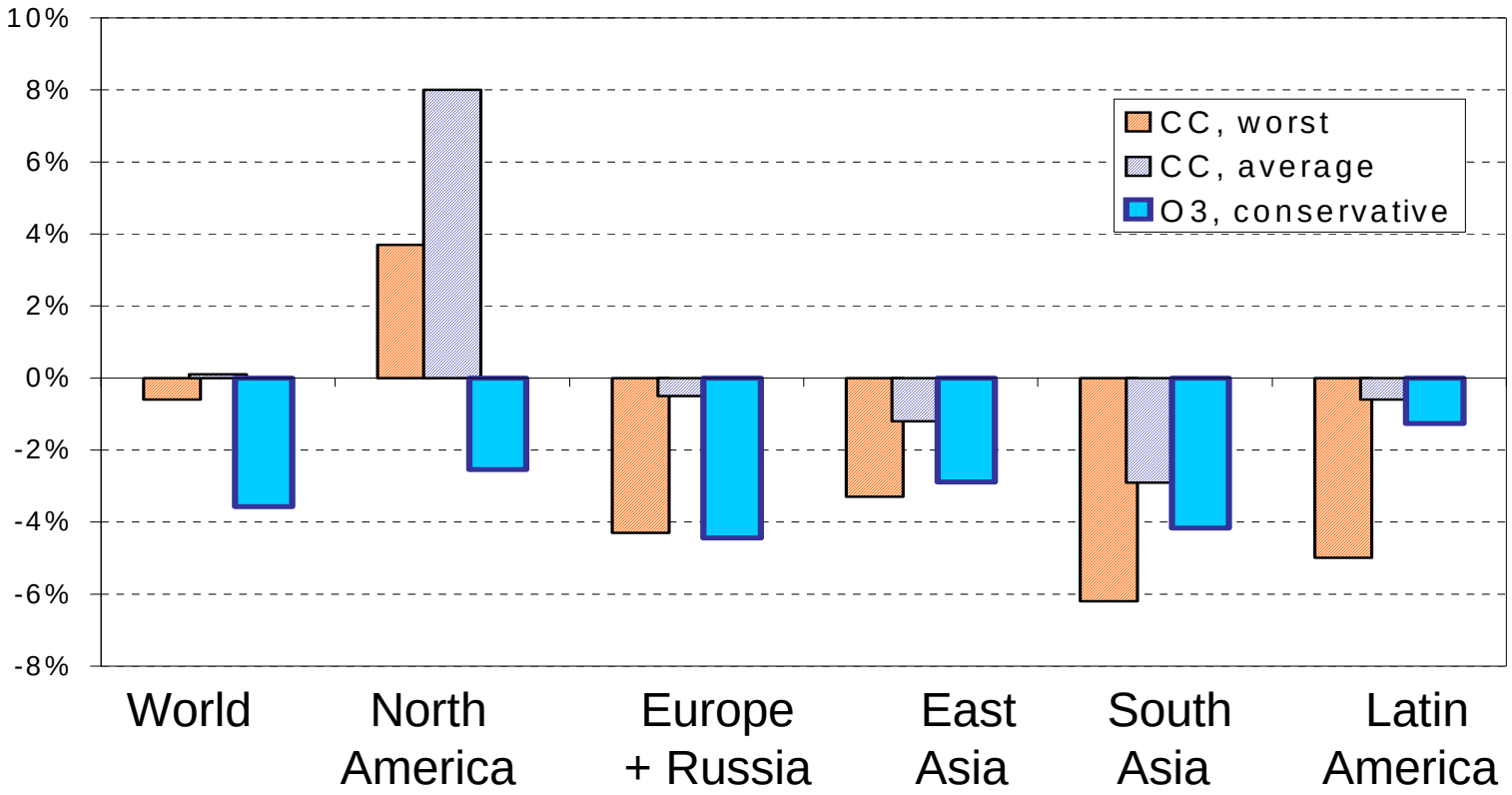
4. Results: Relative Yield Loss change S2-S1



4. Results: change in regional crop production

CC results: Guenther Fischer, IIASA: simulated impact of climate change on regional crop + livestock production – 2080s

O3 results: regional crop production loss 2030 (M7, M12)

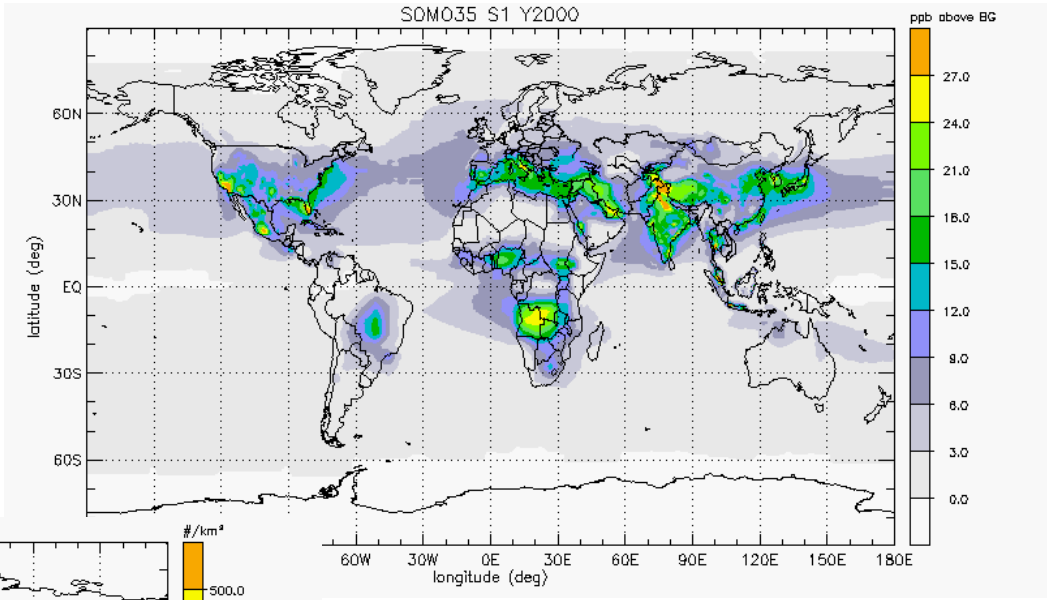


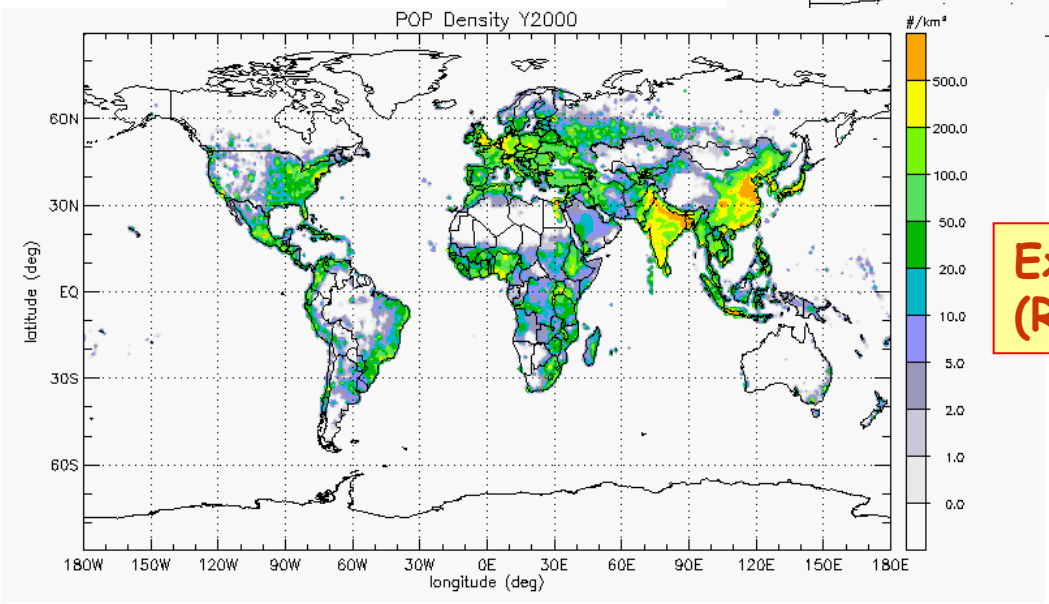
5. Ozone impact on human health

- Overlay SOMO35 with population density and base mortality data

(national base mortality from WHO- burden of disease project)

Relative risk O_3:
RR= 1.0033 for each 10 µg/m³ SOMO35





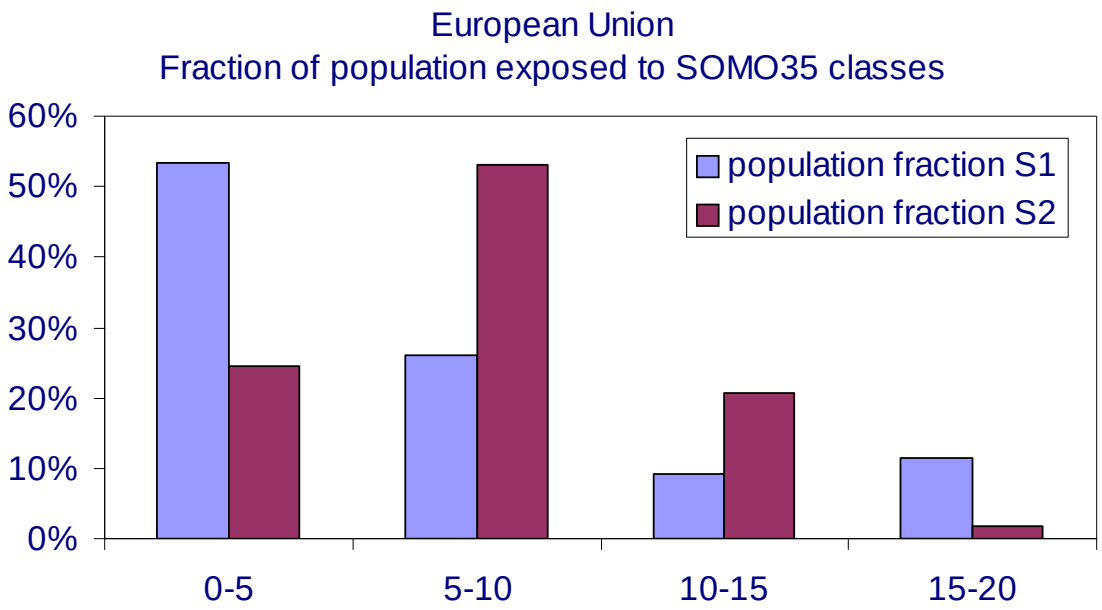
Excess Deaths:
(RR-1)/RR*BM*SOMO35/10*POP

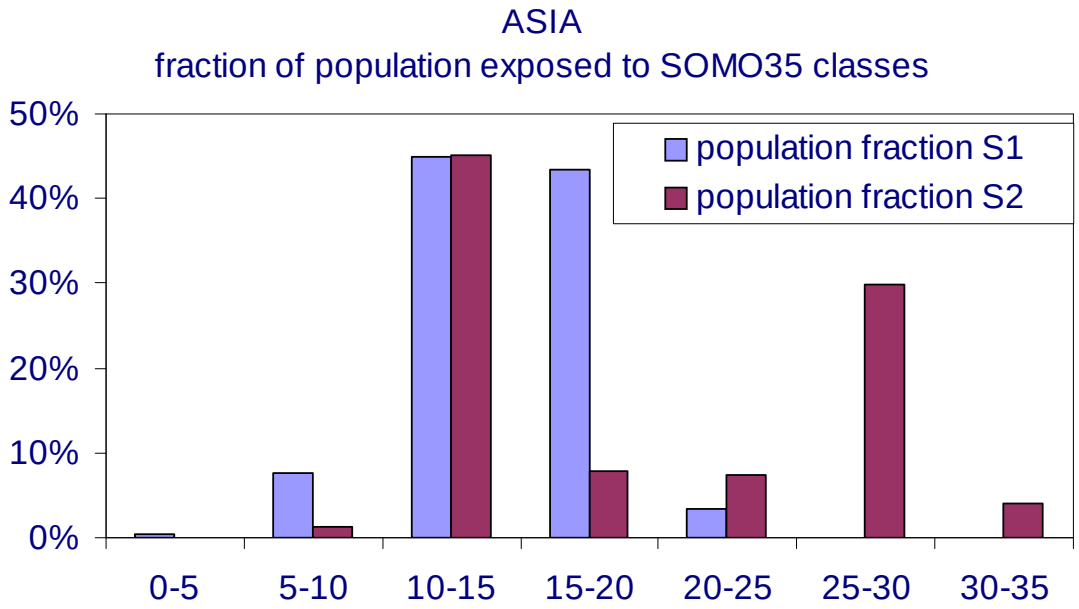
5. Impact on human health: S2-S1

Excess mortalities due to O_3

	AFRICA	EUROPE	ASIA	CHINA	INDIA	L. AMERICA	N. AMERICA
S1	35890	16145	131757	33016	55622	3472	11016
S2	44201	18454	193027	34203	89831	4066	10219
delta	8311	2309	61270	1187	34209	594	-797

5. Impact on human health: increased BG vs. peak O3





6. Conclusions

- Global crop yield losses for 4 crops have been estimated
  in a consistent way
  using the least sophisticated but most robust indicator (M7-M12)
  giving a conservative result

- For year 2000: 3.0% globally but large spread individual countries
- For year 2030: 3.6%

- Stomatal flux approach leads to higher loss estimates.

- Highest expected increase in crop yield losses: India, Pakistan

- Crop yield loss due to ozone comparable to (larger than) CC damage to agriculture

- Important inconsistencies exist between RYL from different indices

6. Uncertainties

Sources of uncertainty

- Emissions

- Model resolution (horizontal/vertical)
- Chemistry
- Transport (tropical regions, Monsoon,…)

- Crop damage functions (recent FACE results?)
- Evaluation of stomatal flux

- Crop distribution, growing season

6. Outlook

- Include climate change
  - Effect on stomatal flux
  - Effect on land use and crop location, agricultural practice
  - Effect on pests and diseases
- Effect of crop losses on supply/demand/trade
- Effect of air pollution on carbon sequestration