

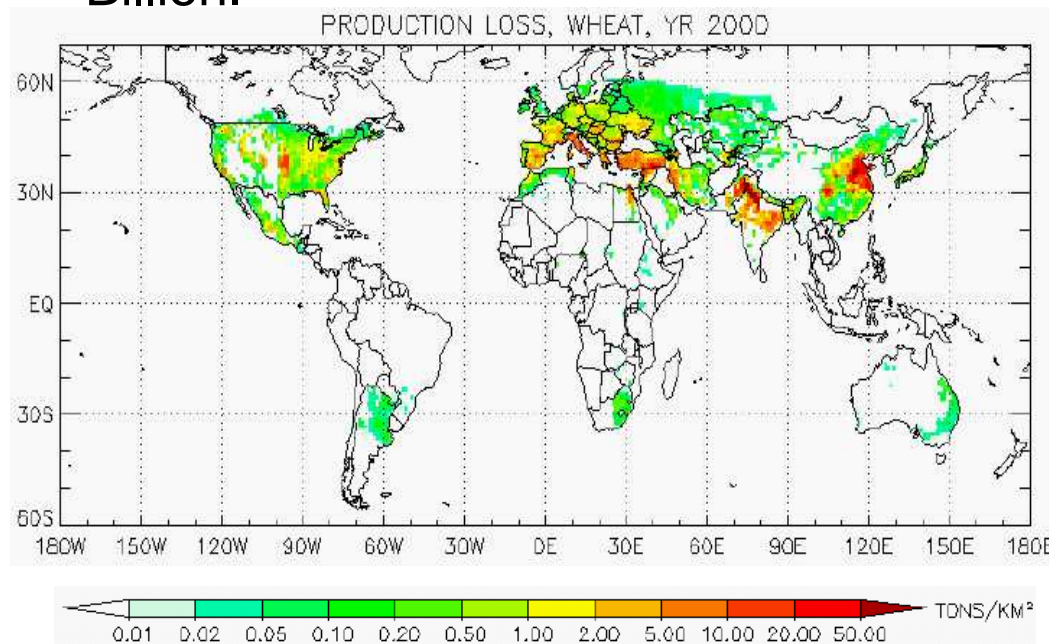
Key Findings Related to  
**Ecosystem and  
Climate Change Impacts**  
of O<sub>3</sub> and PM

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# O<sub>3</sub> Impacts on Terrestrial Ecosystems

- Free-air fumigation experiments demonstrate significant impacts on vegetation from increases in baseline O<sub>3</sub> concentrations.
- Global crop yield losses due to exposure to ozone are estimated to be between 3-16%, depending on the crop, and are valued at \$14 - 26 Billion.



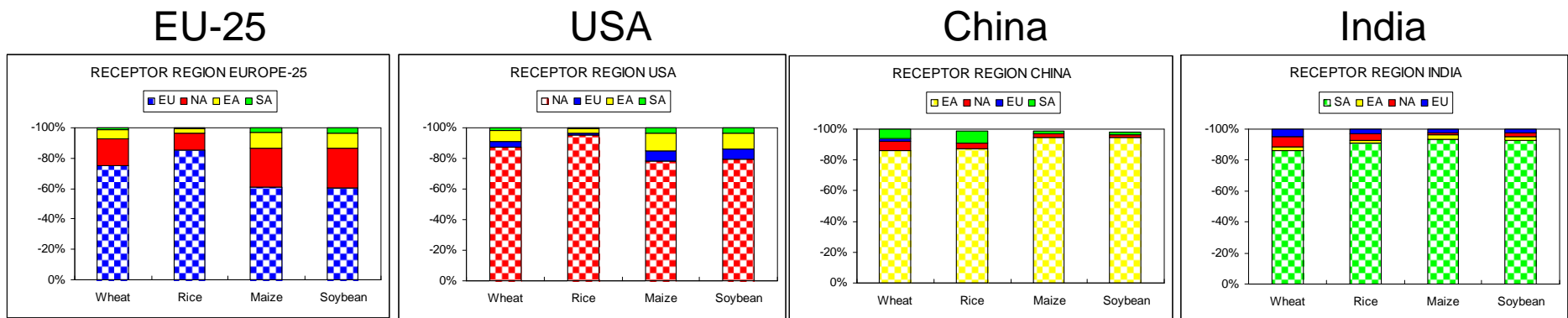
**Average wheat crop  
production losses due  
to O<sub>3</sub>**

van Dingenen et al.[2009]

- Impacts effect vulnerable and important agricultural ecosystems across the northern hemisphere, with important implications for food security, and may be an important factor in the yield gap observed across Asia.

# O<sub>3</sub> Impacts on Terrestrial Ecosystems

- Intercontinental transport may be responsible for up to 40% of the estimated crop yield losses depending on the location, crop, and response function used.



- However, there is significant uncertainty in these estimates, part of which is due to the limited representativeness of available exposure-response functions based on threshold indices (e.g. AOT40, SUM06).
  - Need for exposure-response functions for Asian conditions.
  - Flux-based functions that incorporate differences in species and conditions may better capture effects of intercontinental transport.

# PM Impacts on Terrestrial Ecosystems

- Deposition of acidifying PM damages a variety of different ecosystems including crops, forests and grasslands.
- PM deposition also contributes to eutrophication, which can be damaging to biodiversity in fragile ecosystems.
- Elevated PM concentrations increase diffuse solar radiation reaching vegetation, enhancing the efficiency of photosynthesis.

# O<sub>3</sub> Impacts on Climate

- O<sub>3</sub> contributes significantly to climate forcing,
  - Directly as a greenhouse gas that causes warming
  - and indirectly by damaging plants inhibiting their natural uptake of CO<sub>2</sub>.
- Among ozone precursors, widespread reductions in emissions of CH<sub>4</sub>, CO, and VOCs better reduce net climate forcing than reducing NO<sub>x</sub>, which may increase forcing over decadal time scales.
- Decreasing emissions of CH<sub>4</sub>, which is a greenhouse gas itself, will result in near-term (decade) decreases in the direct forcing from CH<sub>4</sub> and the direct and indirect forcing of O<sub>3</sub>.

# PM Impacts on Climate

Change of global annual average TOA all-sky aerosol direct RF in response to the 20% reduction of anthropogenic emissions (unit:  $\text{mW m}^{-2}$ , mean  $\pm$  std. dev)

| Source Region | Sulfate         | POM           | BC               | Sulfate+POM+BC  |
|---------------|-----------------|---------------|------------------|-----------------|
| NA            | 16.1 $\pm$ 5.6  | 1.6 $\pm$ 1.0 | -4.5 $\pm$ 1.9   | 13.2 $\pm$ 5.2  |
| EU            | 26.7 $\pm$ 9.5  | 1.9 $\pm$ 1.2 | -7.4 $\pm$ 2.3   | 21.2 $\pm$ 9.5  |
| EA            | 19.6 $\pm$ 7.2  | 3.2 $\pm$ 1.8 | -14.5 $\pm$ 8.0  | 8.4 $\pm$ 10.2  |
| SA            | 6.1 $\pm$ 1.9   | 2.5 $\pm$ 1.3 | -5.5 $\pm$ 2.4   | 3.1 $\pm$ 3.2   |
| NA+EU+EA+SA   | 68.4 $\pm$ 22.9 | 9.1 $\pm$ 5.0 | -31.9 $\pm$ 13.7 | 45.9 $\pm$ 24.6 |

The largest climatic impacts do not necessarily occur where the radiative forcing occurs.

# Future Directions and Next Steps

## Main Recommendations

# Improving Our Knowledge Base

- A program of monitoring, research, and analysis activities is needed that is
  - **Intentional**, making source attribution on global to intercontinental scales an explicit objective of on-going and future efforts
  - **Innovative**, employing novel techniques and developing new methods where needed
  - **Integrated**, generating new insights by combining and comparing information within disciplines and across disciplines, as well as across different pollutants
  - **Inclusive**, engaging a broader community of scientists and air quality management officials in developed and developing countries throughout the Northern Hemisphere.
  - Supported by **institutions** and **information networks**, fostering and facilitating cooperation between experts within and across disciplinary and community boundaries

<http://www.htap.org>

## *Main Recommendations*

### **From Knowledge to Action**

- The costs and implications of sector-based control strategies of intercontinental transport should be explored.
- For Hg and POPs, global forums now exist for addressing the mitigation of emissions sources.
- No global or hemispheric institution exists that addresses O<sub>3</sub> and PM. A global confederation of regional cooperative agreements that can maintain linkages to global institutions may be the best path forward.
- The TF HTAP can continue to play a leadership role in bringing together different expert communities and connecting different regional and global institutions. For the LRTAP Convention, continuing and expanding such efforts is important.

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## *Where do we go from here?*

# **Next Steps for EMEP & TF HTAP**

- **Emissions Inventories and Projections**
  - Improving Data, especially for other regions of the world
- **Global and Regional Modeling**
  - Improving Connections Between Global and Regional Scale
  - Building on AC&C and IPCC AR5 Efforts
- **Monitoring Strategy**
  - Identifying Key Assets and Gaps, Connections to New Global Efforts
  - Developing Fingerprinting Techniques, Demonstrating Value of Source Apportionment Information
- **Impact Assessment**
- **Integrated Assessment Modeling**
  - Assessing Differences in Costs and Availability of Control Measures
- **Information Infrastructure**
- **Outreach to Other Regions**

# Questions for Discussion

- Is there additional science that we should account for in the finalization of the 2010 HTAP Assessment?
- Are the findings well supported? Are there caveats and uncertainties that need to be discussed further?
- Are the most important policy-relevant messages highlighted and communicated clearly?
- What further efforts are needed to improve our understanding of intercontinental transport?
- What further studies are needed to inform policy decisions?
- How should the TF HTAP work plan evolve?