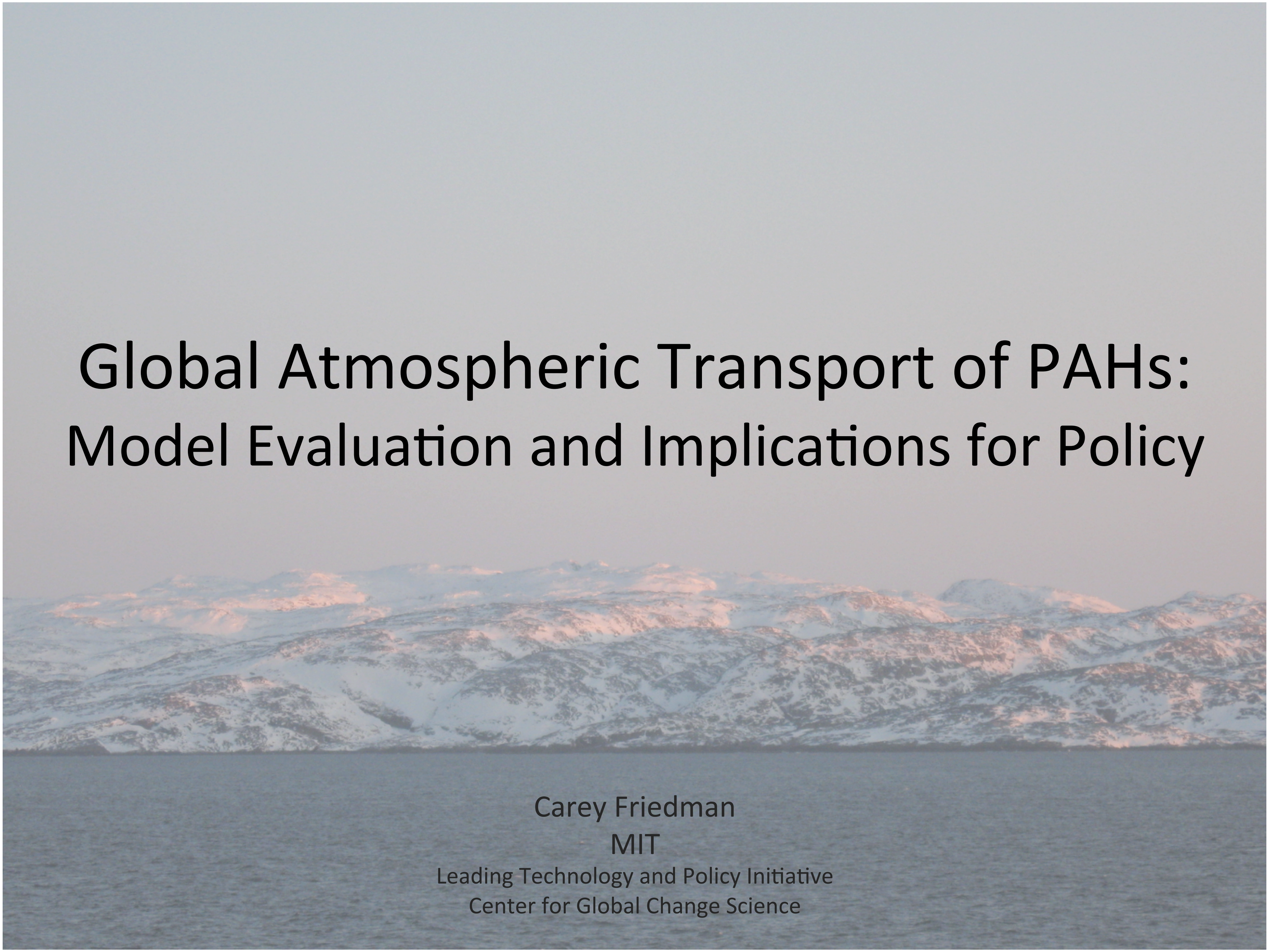


Global Atmospheric Transport of PAHs: Model Evaluation and Implications for Policy

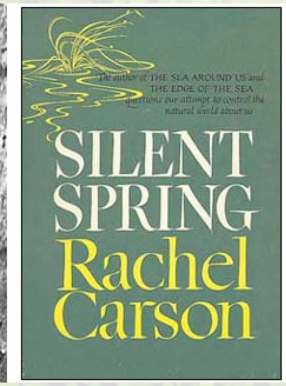
Carey Friedman
MIT
Leading Technology and Policy Initiative
Center for Global Change Science

In this talk

- Background
  - History of persistent organic pollutants (POPs)
  - Two major treaties aimed at reducing POP concentrations
    - The Convention on Long-Range Transboundary Air Pollution (CLRTAP)
    - The Stockholm Convention
- Results from our work
  - Global atmospheric transport of polycyclic aromatic hydrocarbons (PAHs)

A history of POPs

- Public awareness of hazardous chemicals began in the 1960/70s
  - Carson warned of the impacts of DDT and similar pesticides on non-target animals
  - PCBs linked to “chloracne” and found in widespread environmental samples
  - Agent Orange used in Vietnam war



A history of POPs (cont'd)

- Discovery of long-range transport and contamination of "pristine" environments in the 1980s
- Discovery of three significant common factors
  - High levels in the Arctic
  - Evidence of non-local sources
  - Evidence of human and environmental health detriment
    - High levels in Inuit women and breast milk

Political Action

- Initial efforts (early 1970s)
- Call for stronger international legal measures
  - Largely voluntary at this point
  - Environmental groups and countries called for greater international protection

Major hazardous chemicals treaties

- Basel Convention (1989)
  - Waste
- Rotterdam Convention (1998)
  - Trade

POPs Treaties:

- Convention on Long-Range Transboundary Air Pollution (1998)
  - *Regional*
- Stockholm Convention (2001)
  - *Global*

LRTAP
Long-range Transboundary Air Pollution

Stockholm Convention
on persistent organic
pollutants (POPs)

CLRTAP POPs Protocol

- First multilateral treaty specifically on POPs
- Spurred by high POP concentrations in the Arctic
  - Canada sought international regulatory measures
- Task force formed
  - Divided POPs into categories
    - Intentionally produced
    - Non-intentionally produced
  - Coined the term "POPs"

CLRTAP POPs Protocol (cont'd)

- Objective
  - Control, reduce, or eliminate discharges, emissions, and losses of POPs
- New substances
  - Combination of scientific criteria combined with risk-characterization
- Regional
  - As of Nov. 2011: 31 countries and the EU have ratified the protocol (not including the US)

The Stockholm Convention

- CLRTAP work spurred interest of IGOs and NGOs
  - UNEP called for global assessments of POPs
- Assessment worked relied heavily on CLRTAP
  - CLRTAP assessments used as data source
  - CLRTAP substances selected
  - CLRTAP mechanism for adding substances

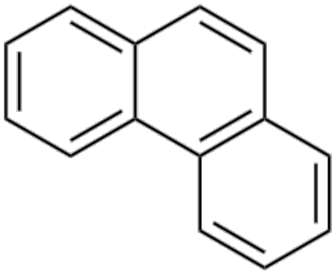
The Stockholm Convention (cont'd)

- Differences with CLRTAP
  - Greater consideration of developing nations
    - "Common but differentiated" responsibilities
      - Polluter pays principle
      - Use exemptions for certain substances
      - Technical and financial assistance committed by developed countries to developing countries
- US has also not ratified the SC

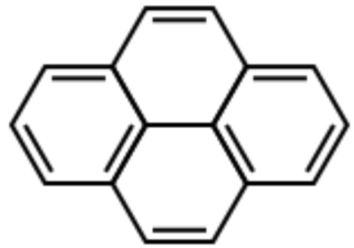
Modeling of global atmospheric POP transport

- Polycyclic aromatic hydrocarbons (PAHs)
- Regulated regionally but not globally
  - Should they be regulated globally?
    - Do they meet long-range transport criteria?
    - Which physicochemical processes is transport sensitive to?
    - Can sources to Arctic/remote areas be identified?
    - How will a future climate affect global distribution?

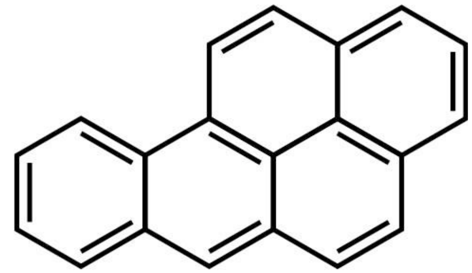
Model parameterizations



Phenanthrene (PHE)



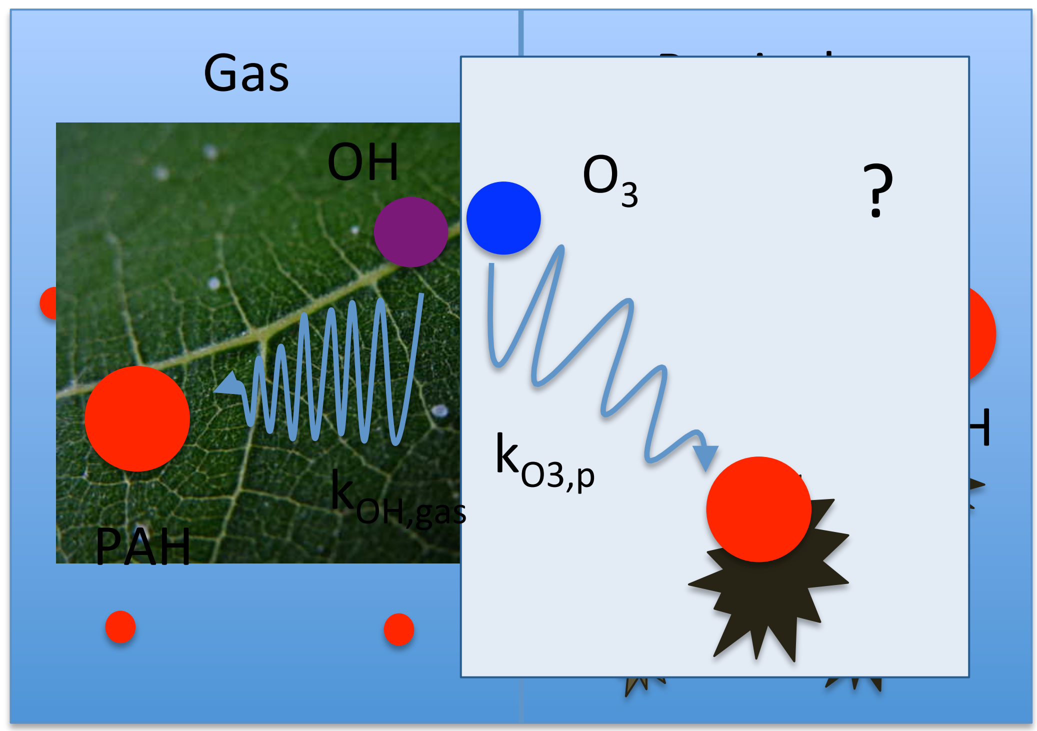
Pyrene (PYR)



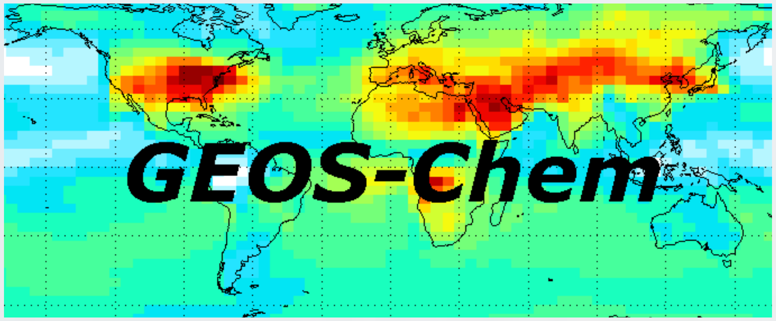
Benzo[a]pyrene (BaP)

100% gas ⟷ 100% particulate

- Gas-particle partitioning
- Oxidation
- Wet deposition
- Dry deposition

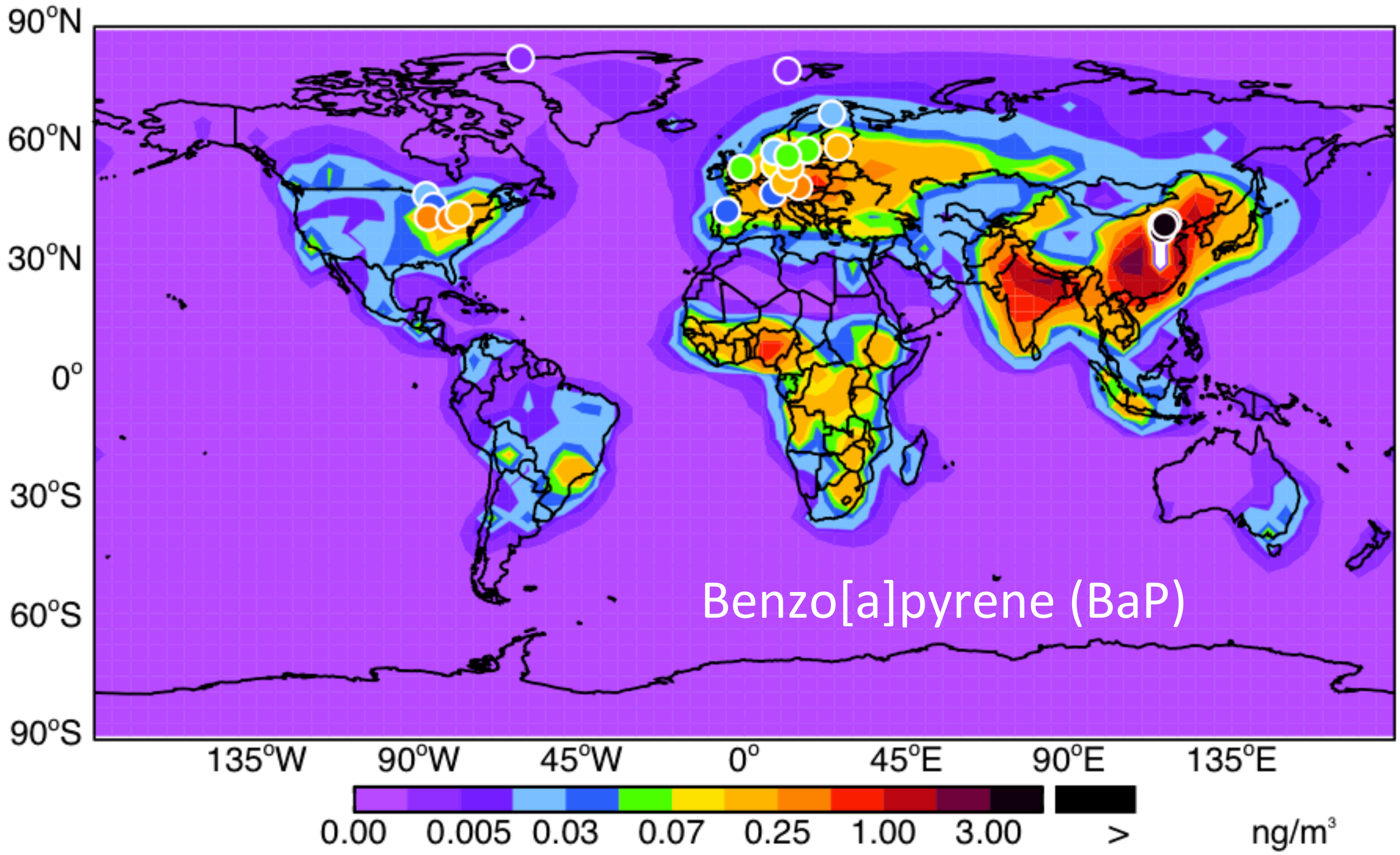


Simulation Details



- Global emissions from Zhang and Tao
  - (*Atmos. Environ.*, 2009, 43:812-819)
- GEOS5 meteorology
  - 4° × 5°
  - 47 levels
  - 6 or 3-hr temporal resolution
- Runs completed for 2004-2009
  - 2004 used as initialization

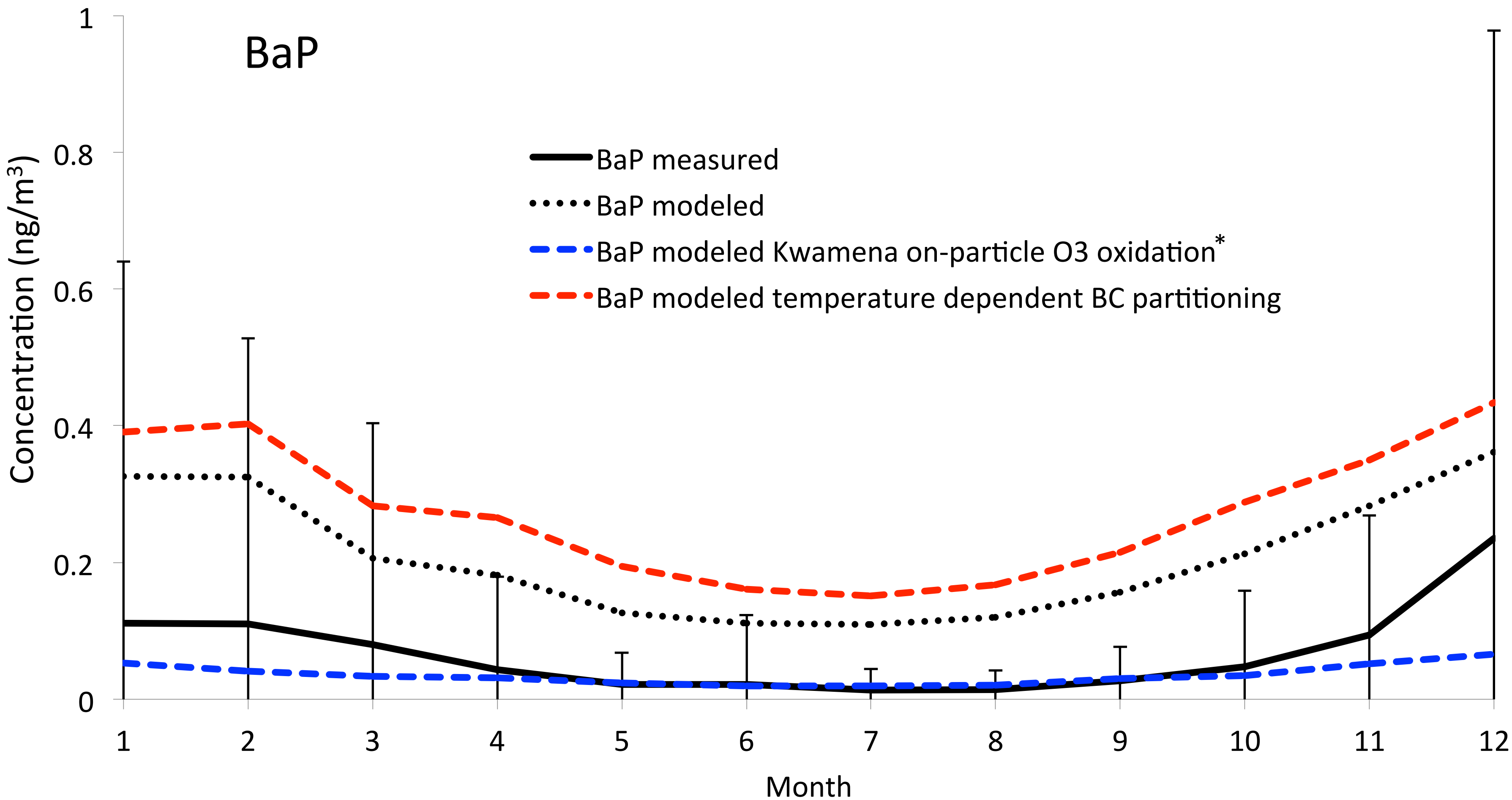
Mean total (gas + particulate) observed vs. modeled: 2005-2009



Non-urban, land based: r = 0.80 (PHE), r = 0.85 (PYR), r = 0.86 (BaP)

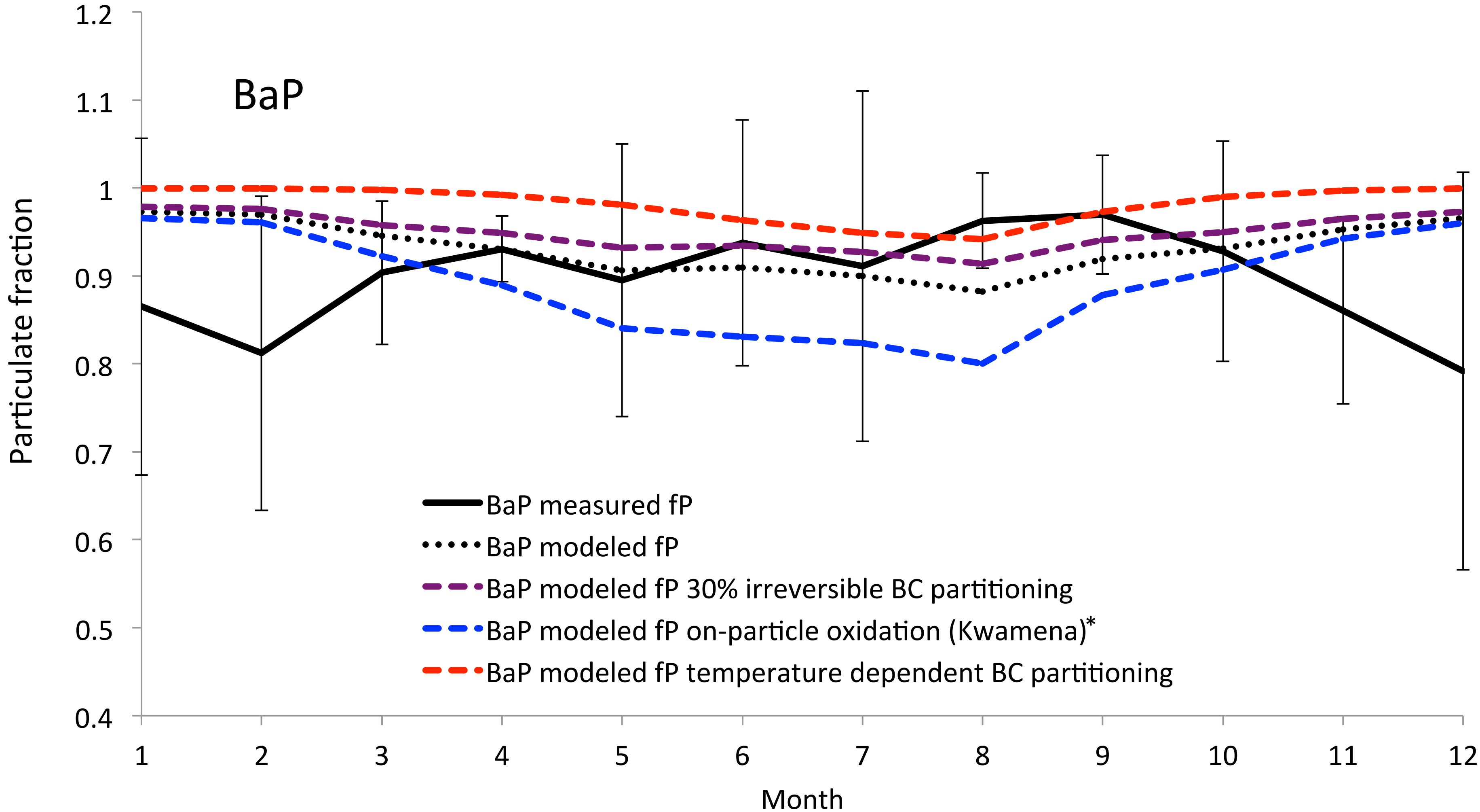
Atmospheric lifetimes (days): 0.65 (PHE), 0.52 (PYR), 0.70 (BaP)

Seasonality and sensitivity analyses: Mean non-urban mid-latitude concentrations



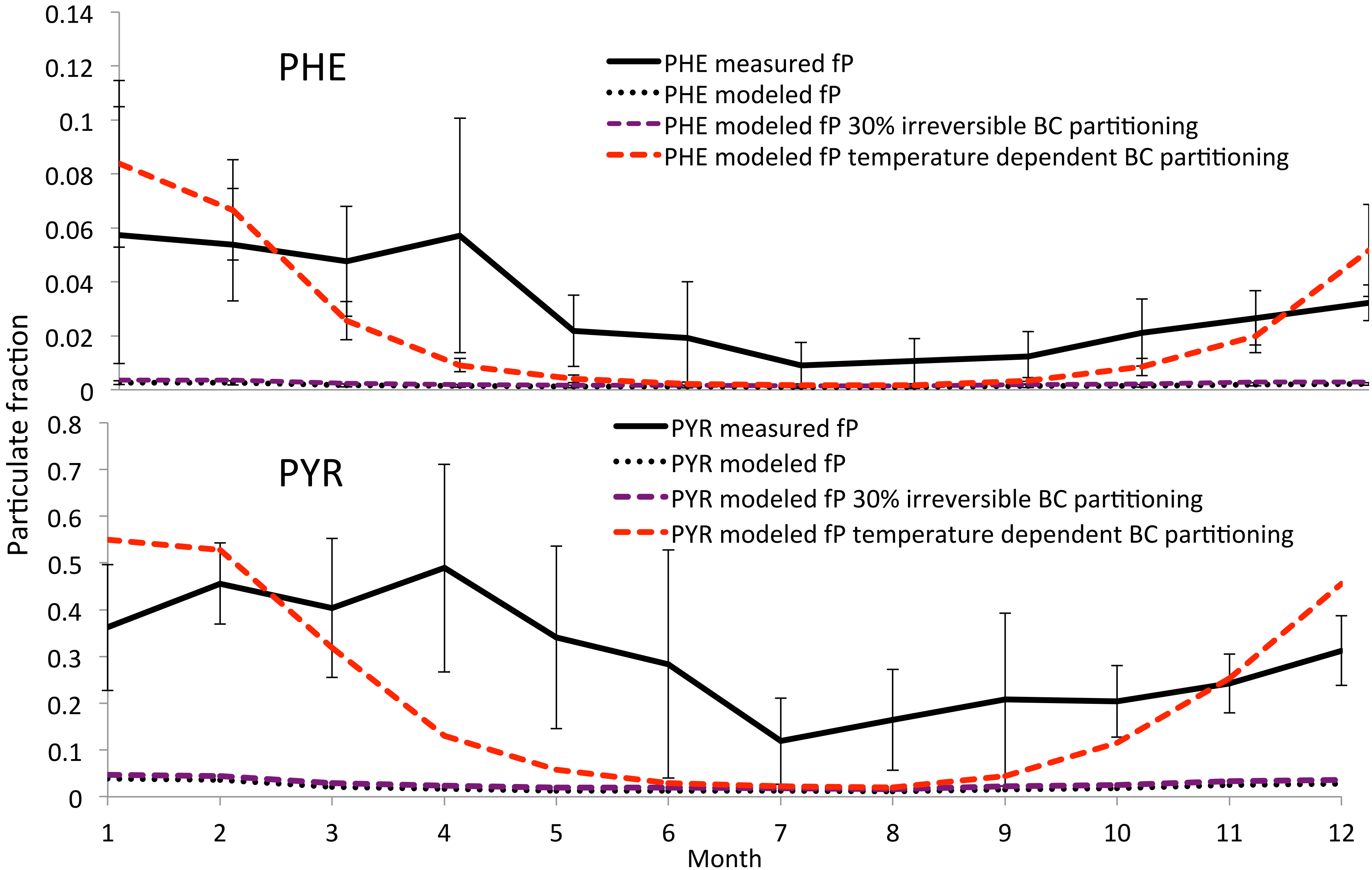
*Kwamena *et al*. 2007 *Atmos. Environ.* 41:37-50

Seasonality and sensitivity analyses: Particulate fraction

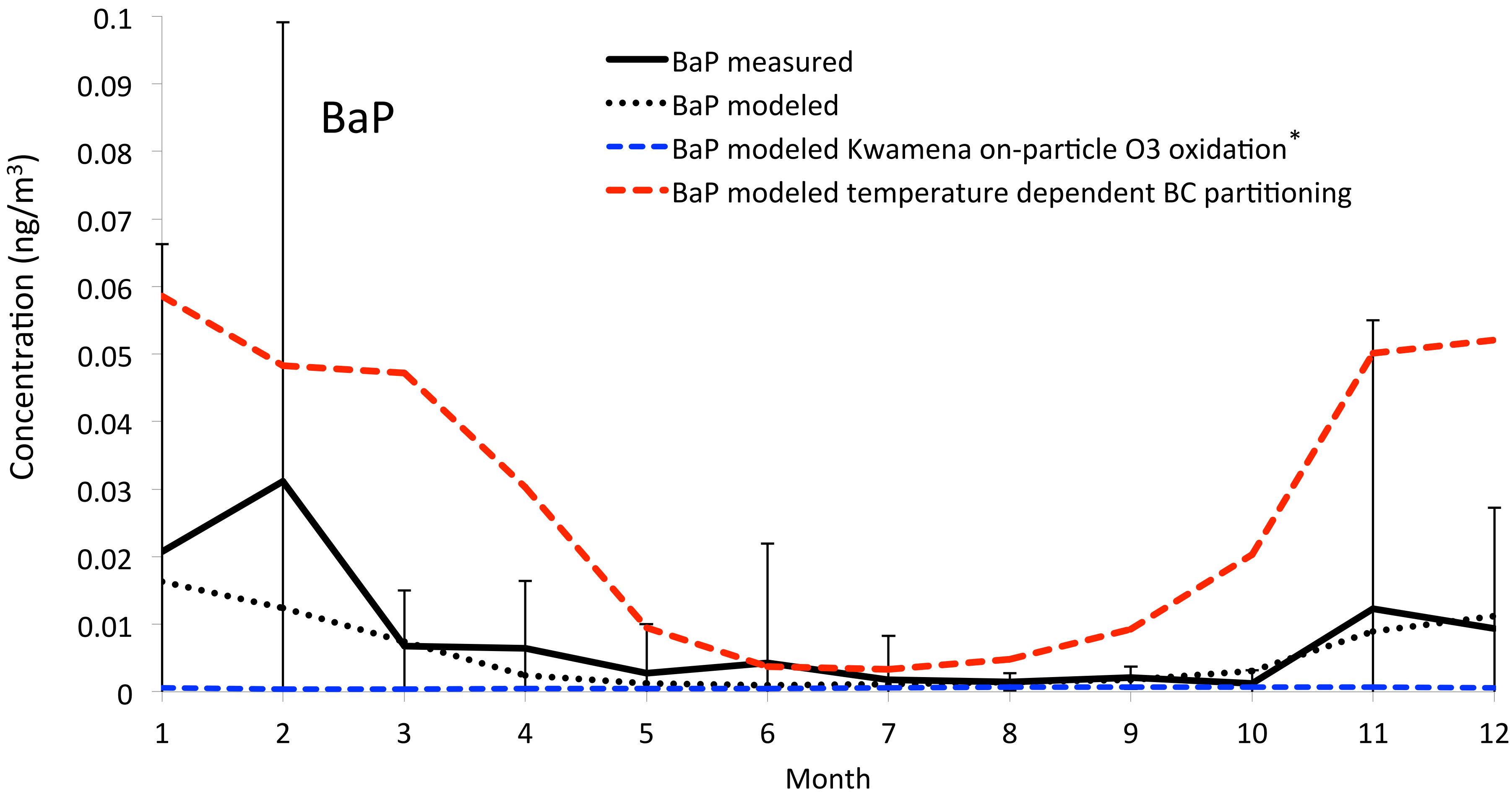


*Kwamena *et al*. 2007 *Atmos. Environ.* 41:37-50

Seasonality and sensitivity analyses: Particulate fraction

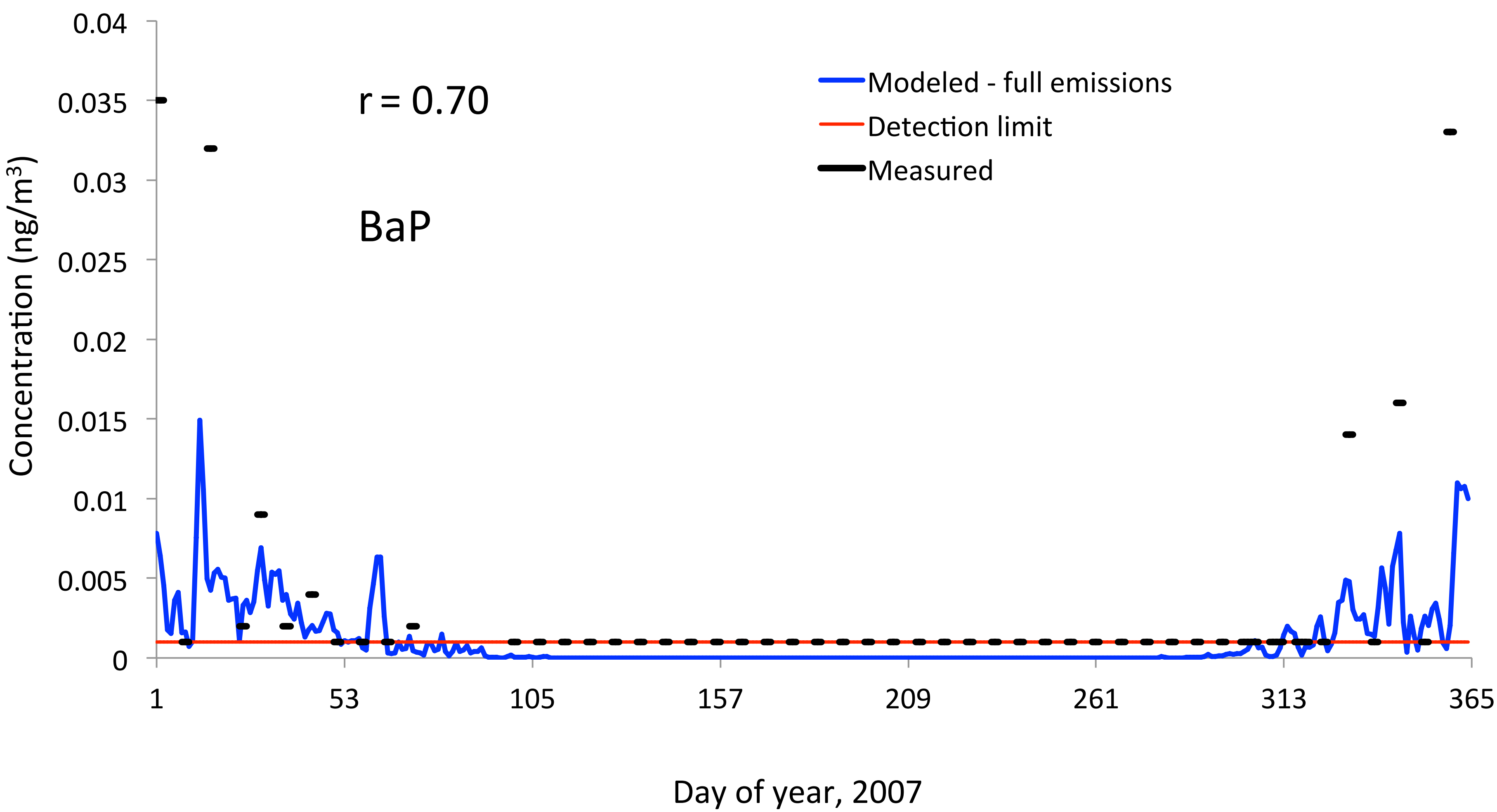


Seasonality and sensitivity analyses: Mean Arctic concentrations

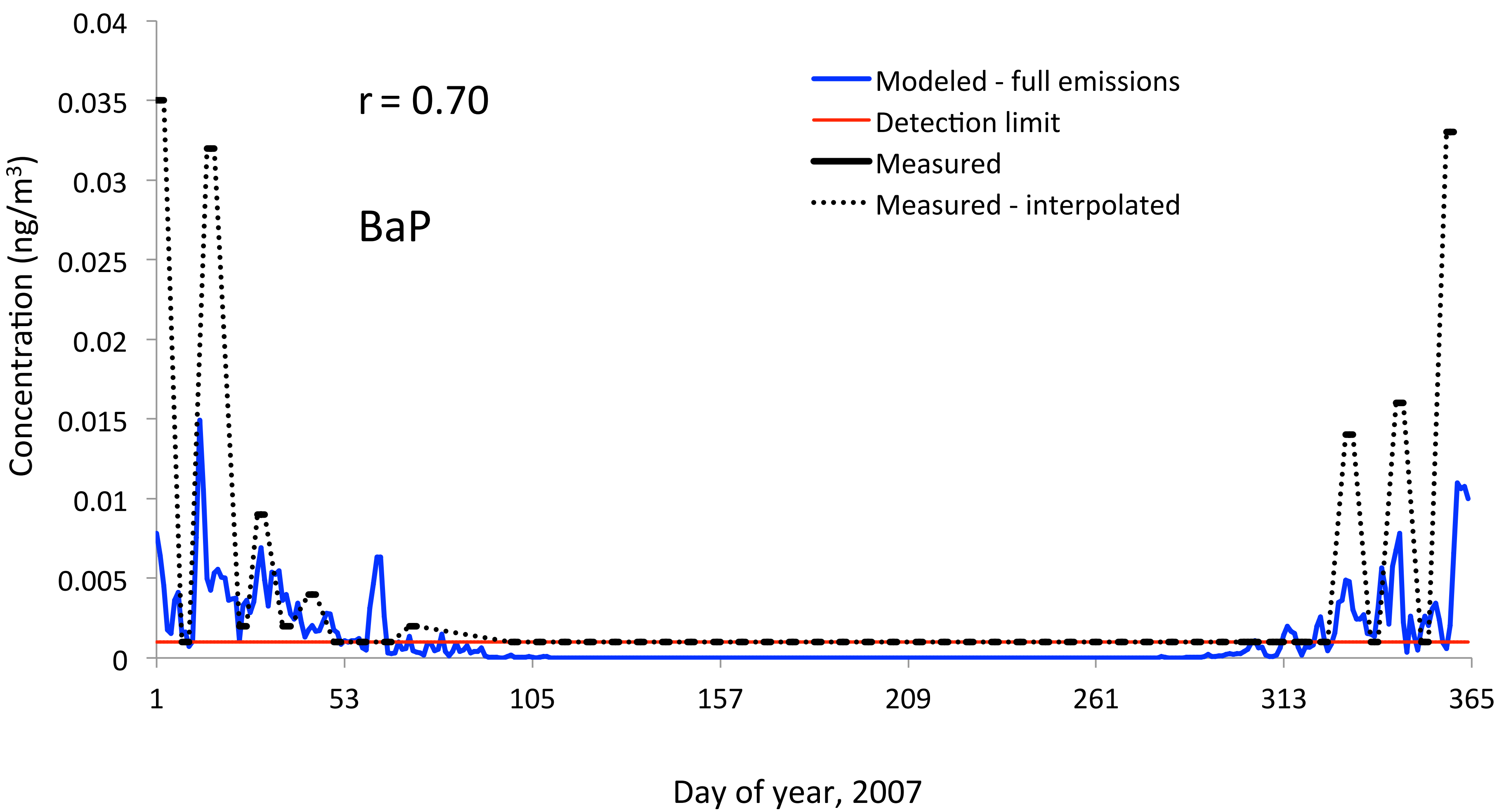


*Kwamena *et al*. 2007 *Atmos. Environ.* 41:37-50

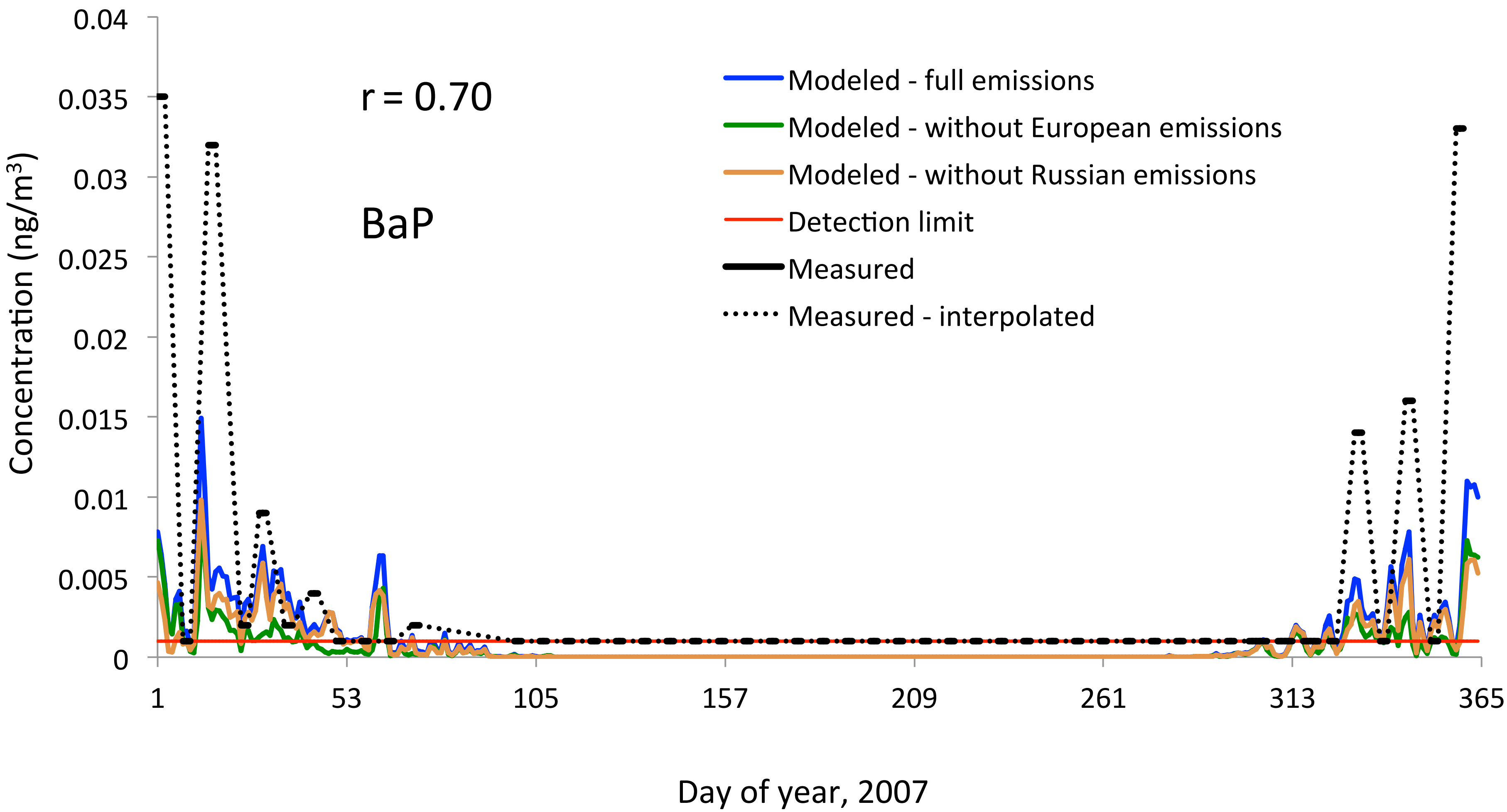
Time series:
Arctic (Spitsbergen, Norway) concentrations



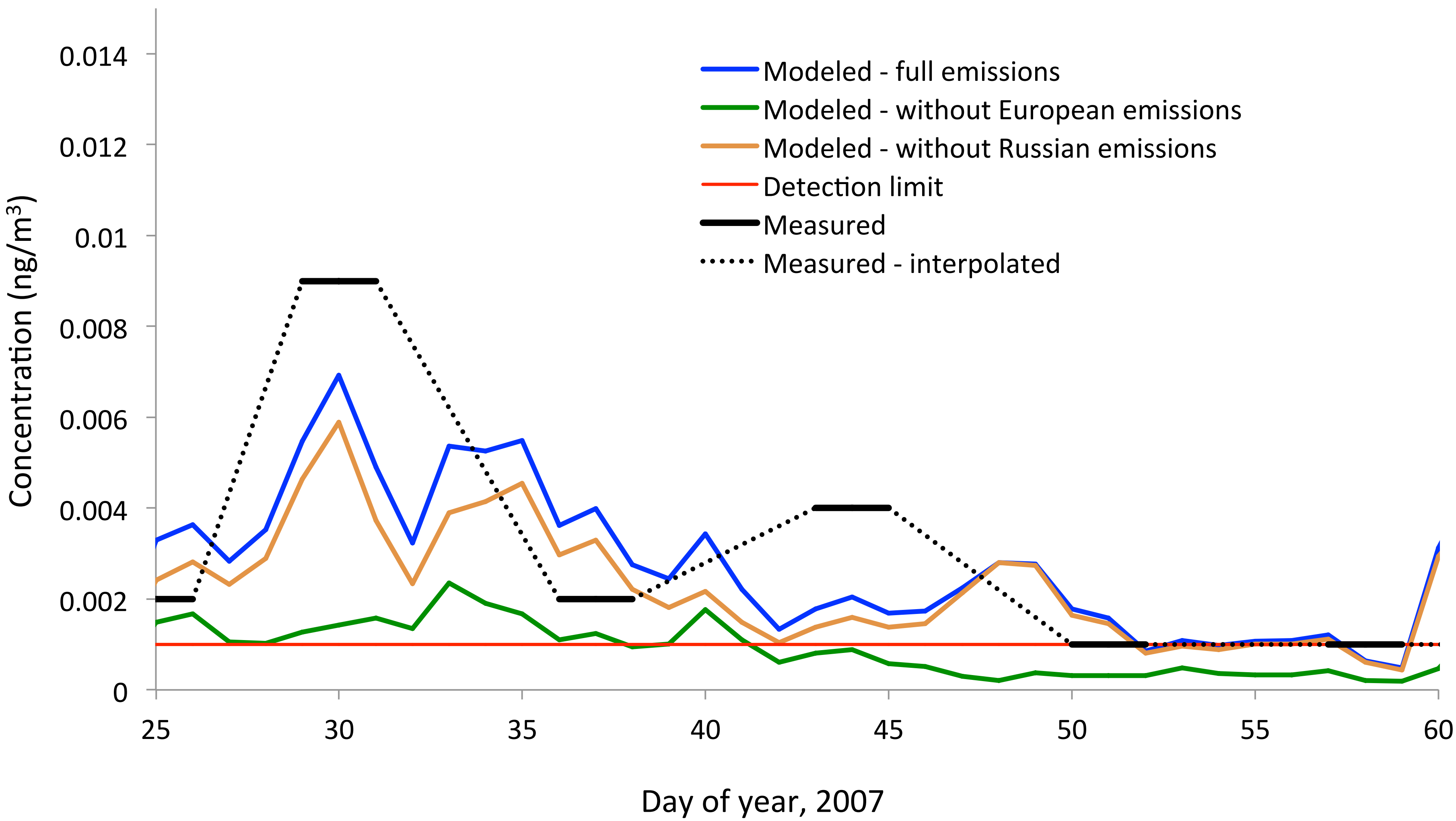
Time series: Arctic (Spitsbergen, Norway) concentrations



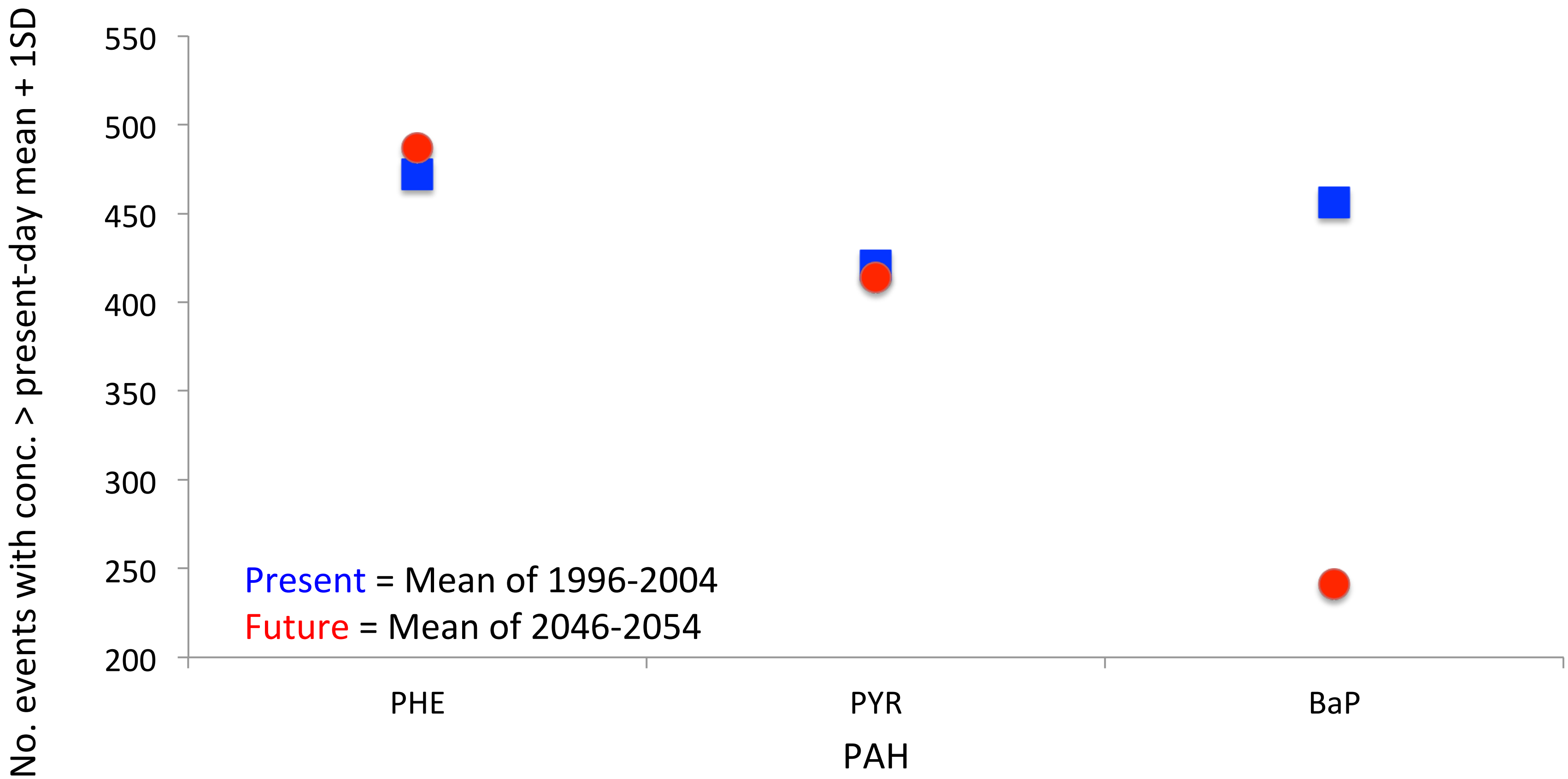
Time series:
Arctic (Spitsbergen, Norway) concentrations



Time series:
Arctic (Spitsbergen, Norway) concentrations



Future climate - Spitsbergen



Present day mean conc. and SD (ng/m^3):

PHE: 0.32 ± 0.43

PYR: 0.046 ± 0.071

BaP: $2.5 \times 10^{-4} \pm 3.0 \times 10^{-4}$

Conclusions

- Transport to remote regions occurs despite an average lifetime < 2.8 days
- Long-range transport depends strongly on temp-dependence of G-P partitioning and on-particle oxidation
- European and Russian emissions most important at Spitsbergen
- PAH behavior in Arctic under a future climate depends strongly on G-P partitioning characteristics

Friedman and Selin, in revision, 2012, ES&T

PAHs as a case study

- How do we better understand the relationship of science and policy through PAHs?
  - Are screening-level thresholds too simplistic? How can models help?
  - What should policy makers be doing to incorporate science?
  - What can scientists do to help policy makers understand the science?

Questions?

Acknowledgments
Noelle Selin
MIT Ferry Fund
LTP Initiative
Abby Koss* (MIT)
Anthony Longboat* (MIT)
Bob Yantosca & GEOS-Chem Support Team (Harvard & Dalhousie)
Marta Venier (Indiana)
Ronald Hites (Indiana)
Hayley Hung (Environment Canada)
Hang Xiao (Environment Canada)
Northern Contaminants Program (Environment Canada)
European Monitoring and Evaluation Programme
Arctic Monitoring and Assessment Programme (AMAP)

*Undergraduate