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# CAM5 Estimates of Global Source-Receptor Relationships for Black Carbon under Present-day Emission Scenario

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Chemistry Climate WG Meeting, 17th Annual CESM Workshop
20 June 2012, Breckenridge, CO

This work has been supported by the DOE Office of Science (BER) Climate Modeling program.

# Introduction: black carbon in CAM5



- The standard CAM5 is not correctly characterizing Arctic BC forcing (signatures are quite similar to other models; Koch et al. 2009); Systematic BC biases include:
  - Over-prediction at high altitudes
  - Under-prediction near surface
  - Poor seasonal cycle
- Contributing factors could be:
  - Wet removal and BC aging (Liu et al., 2012; Wang et al., 2012)
  - Eddy/circulation transports (Ma et al., 2012)
  - Model resolution (Fast et al.,2012; Rasch et al., 2012)
  - Inconsistencies in cloud micro-/macro-physics (Caldwell et al., 2012)
  - Emissions (Wang et al., 2012)

# Motivation and objective



- BC is an important forcing agent in the atmosphere (e.g., direct, indirect and semi-direct effects and associated feedbacks)
- BC in snow and ice can result in more rapid melting (e.g., Warren and Wiscombe, 1980), changing the coupled climate system through snow-albedo feedback (e.g., Flanner et al. 2007)
- Large uncertainties in BC emissions (Bond et al. 2004; Lamarque et al. 2010) and BC prediction by global models
- We use a tagging technique to establish global source-receptor relationships with a focus on the Arctic BC
- To assess climate impact of change in regional BC emissions

# The tagging methods in CAM5

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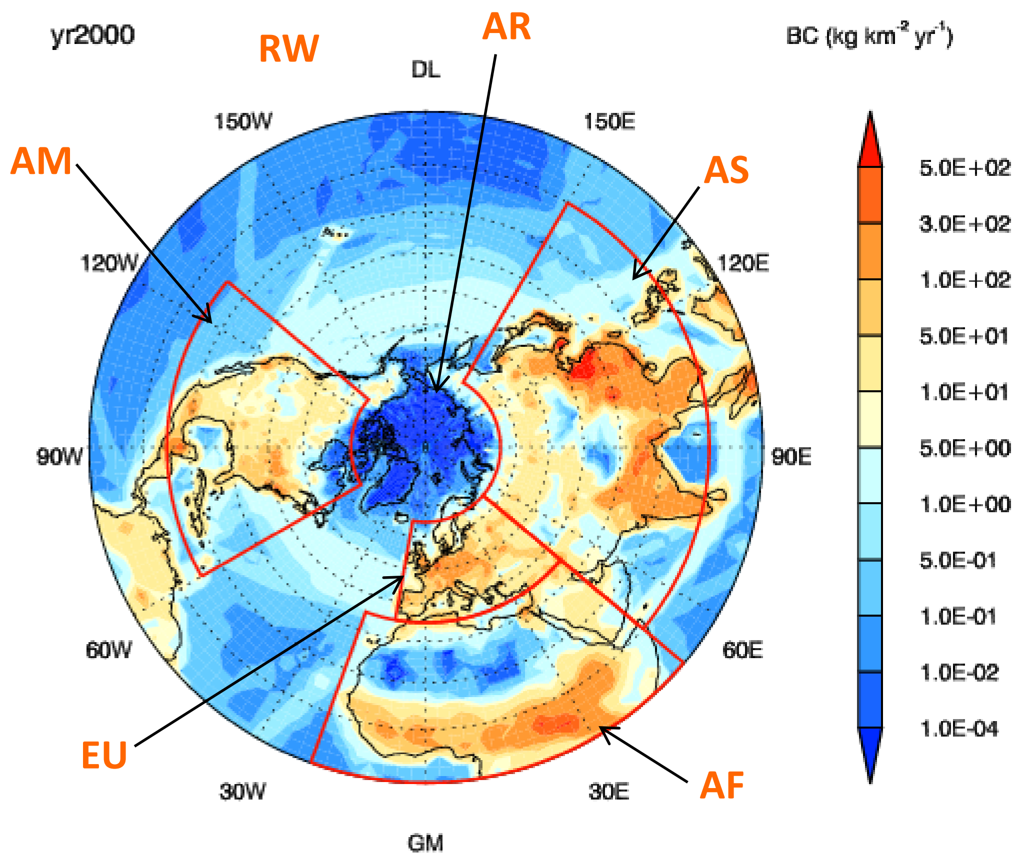
- Simple method:
  - Emissions divided by geographical regions and tagged by flavors
  - Mass tendencies of flavors are derived from those of the original variable, assuming that tendency is proportional to mass.
  - Flavors are explicitly advected
  - Easy to implement but cannot apply to species undergoing transformation
- Explicit (brute-force) method:
  - Do the same to emissions
  - Define a new variable for each of the tagged regions
  - Each variable experiences the same tendency calculations and advection
  - More straightforward and accurate, but more expensive

# BC emission and source/receptor regions



AR5 year 2000 BC emission (Lamarque et al., 2010)




AS: Asia (50-150E, 10-65N)

AM: N. America (60-130W, 15-65N)

EU: Europe (10W-50E, 35-65N)

AF: N. Africa (20W-50E, 0-35N)

AR: Arctic (66.5-90N)

RW: Rest of world

Global: 7.8 Tg/yr
AS: 3.0 EU: 0.83
AF: 0.99 AM: 0.63
AC: 0.008 ROW: 2.33

# CAM5 experiment



- 10-year 2-degree (1.9° x 2.5°) simulation
  - Fixed year 2000 SST
  - The 3-mode modal aerosols (MAM-3; Liu et al. 2012)
  - Improved cloud/precipitation scavenging (Wang et al. 2012)
  - New treatment of convective transport & wet removal of aerosols (Wang et al. 2012)
  - AR5 year 2000 emissions (Lamarque et al. 2010)

# Results: transport pathways of regional BC

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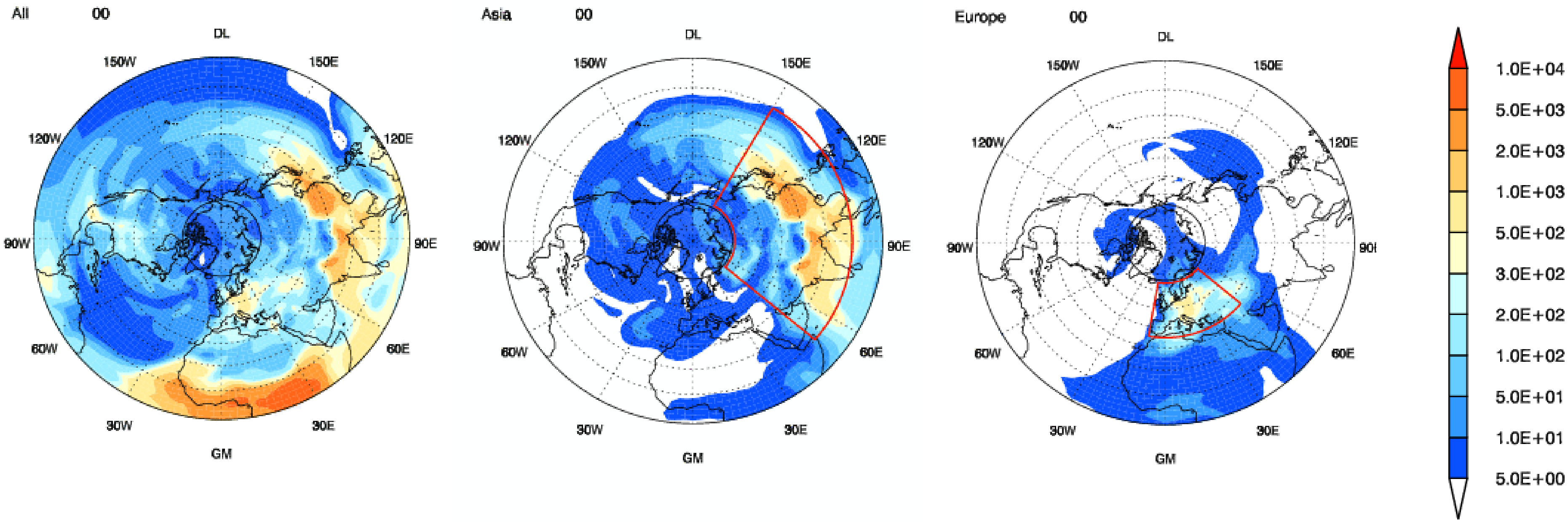
All BC | Asia | Europe




Animation of daily-mean BC atmospheric column burden in January of yr-10

# Results: transport pathways of regional BC

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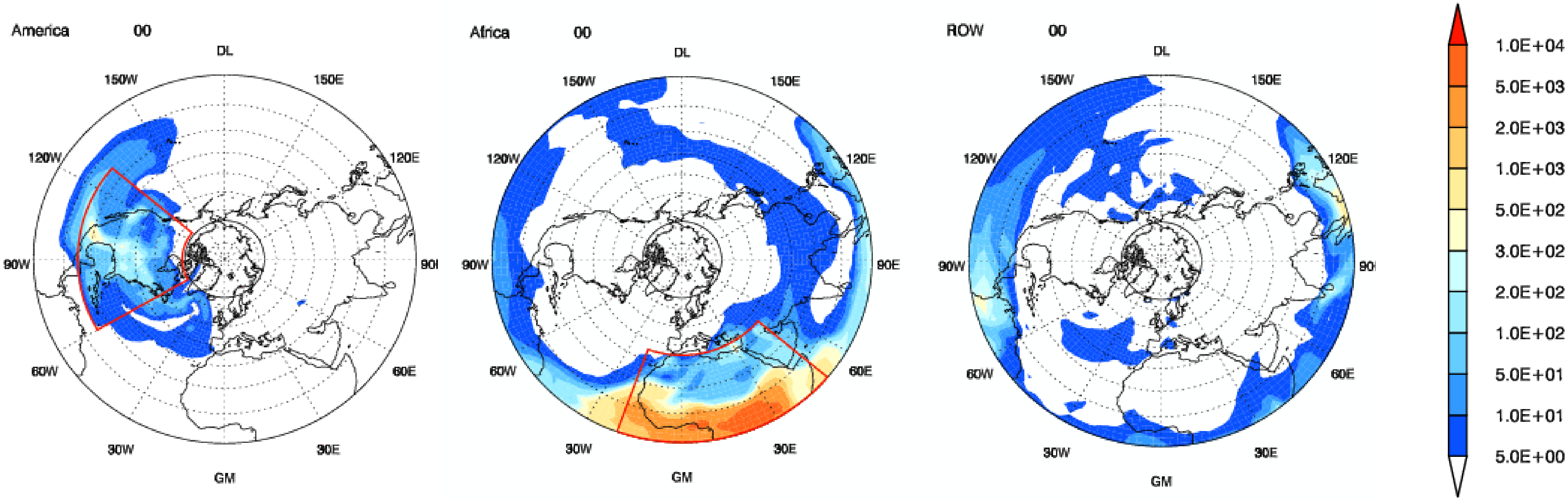
N. America | N. Africa | ROW

BC burden (ug $m^{-2}$)



# Metrics to measure source-receptor relationship



- Contribution of source i to burden in receptor region j

$C_{i,j} = (B_i / \Sigma B_i)_j$

$(\Sigma B_i)_j$ represents the total burden in region j.

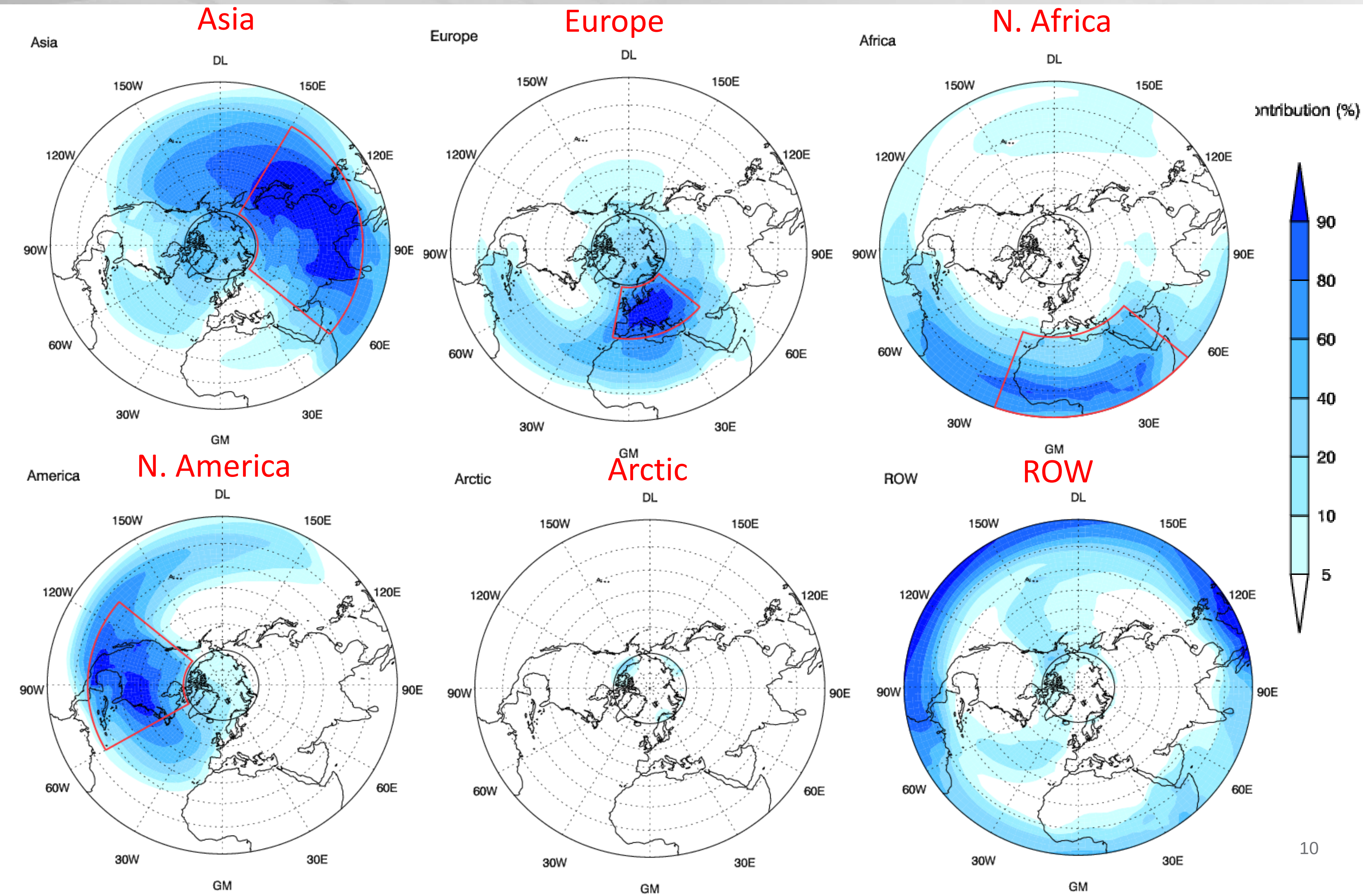
- Efficiency of source i affecting receptor j

$F_{i,j} = C_{i,j} / (E_i / \Sigma E_i)$

$\Sigma E_i$ represents global total emission rate.

# Results: source attribution (ANN)





# Results: source/receptor matrix (ANN)

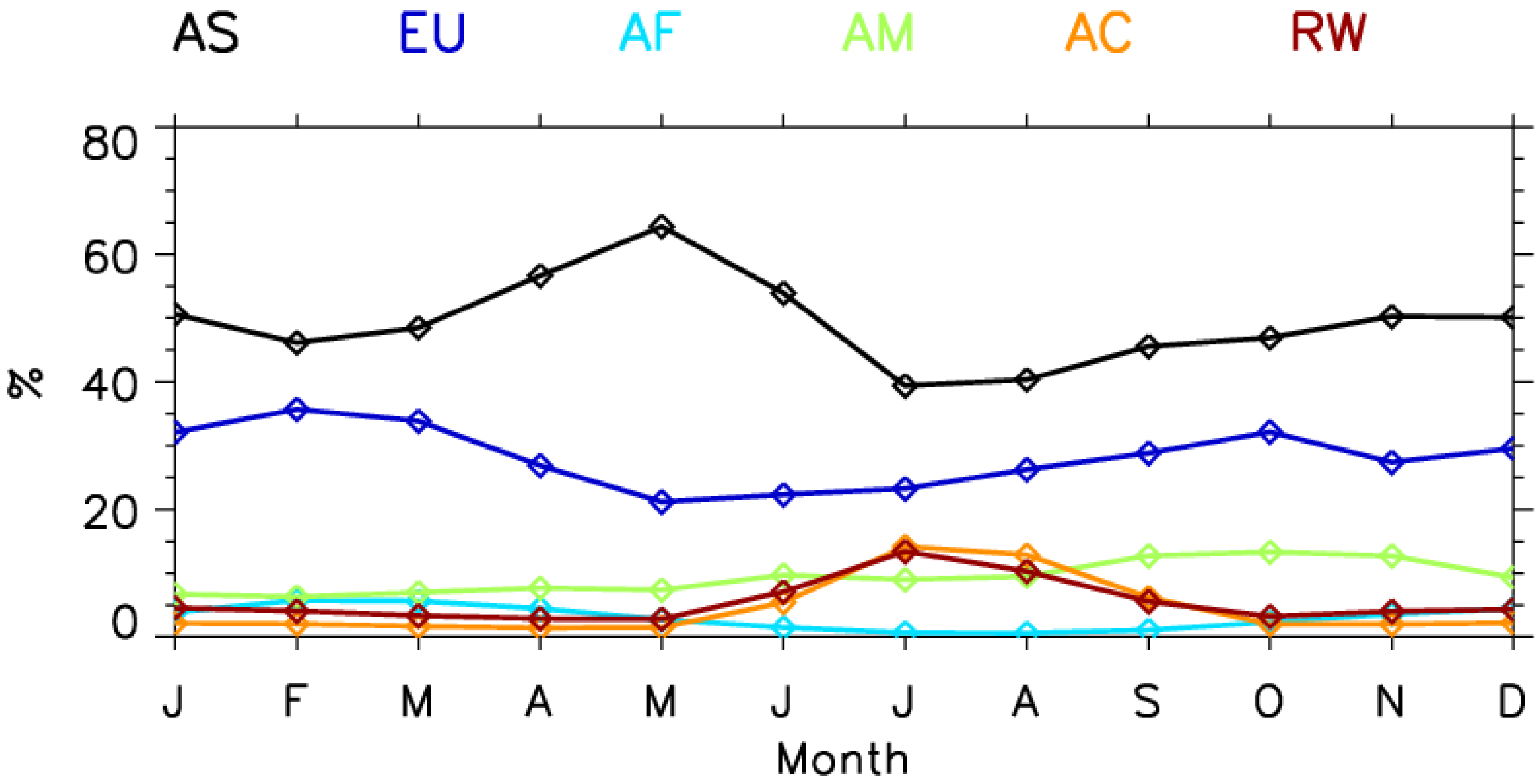
0 5 10 20 30 50 70 90 100 (%)

| source \ receptor | AS | EU | AF | AM | AC | RW | Emis ($Tg\ yr^{-1}$): |
|---|---|---|---|---|---|---|---|
| Burd (Gg): | 24.39 | 5.66 | 16.90 | 5.78 | 0.97 | 42.09 | |
| RW | 1.6 | 0.8 | 16.0 | 2.1 | 5.9 | 67.4 | 2.333 |
| AC | 0.1 | 0.1 | 0.0 | 0.2 | 5.2 | 0.1 | 0.008 |
| AM | 0.6 | 2.9 | 0.8 | 81.4 | 9.0 | 3.2 | 0.632 |
| AF | 3.5 | 3.7 | 65.3 | 2.6 | 2.8 | 17.5 | 0.994 |
| EU | 6.2 | 87.7 | 13.6 | 3.2 | 27.3 | 2.5 | 0.834 |
| AS | 88.0 | 4.8 | 4.1 | 10.4 | 49.8 | 9.2 | 3.005 |

Relative contributions (colored) derived from the global distribution of source attribution for BC burden

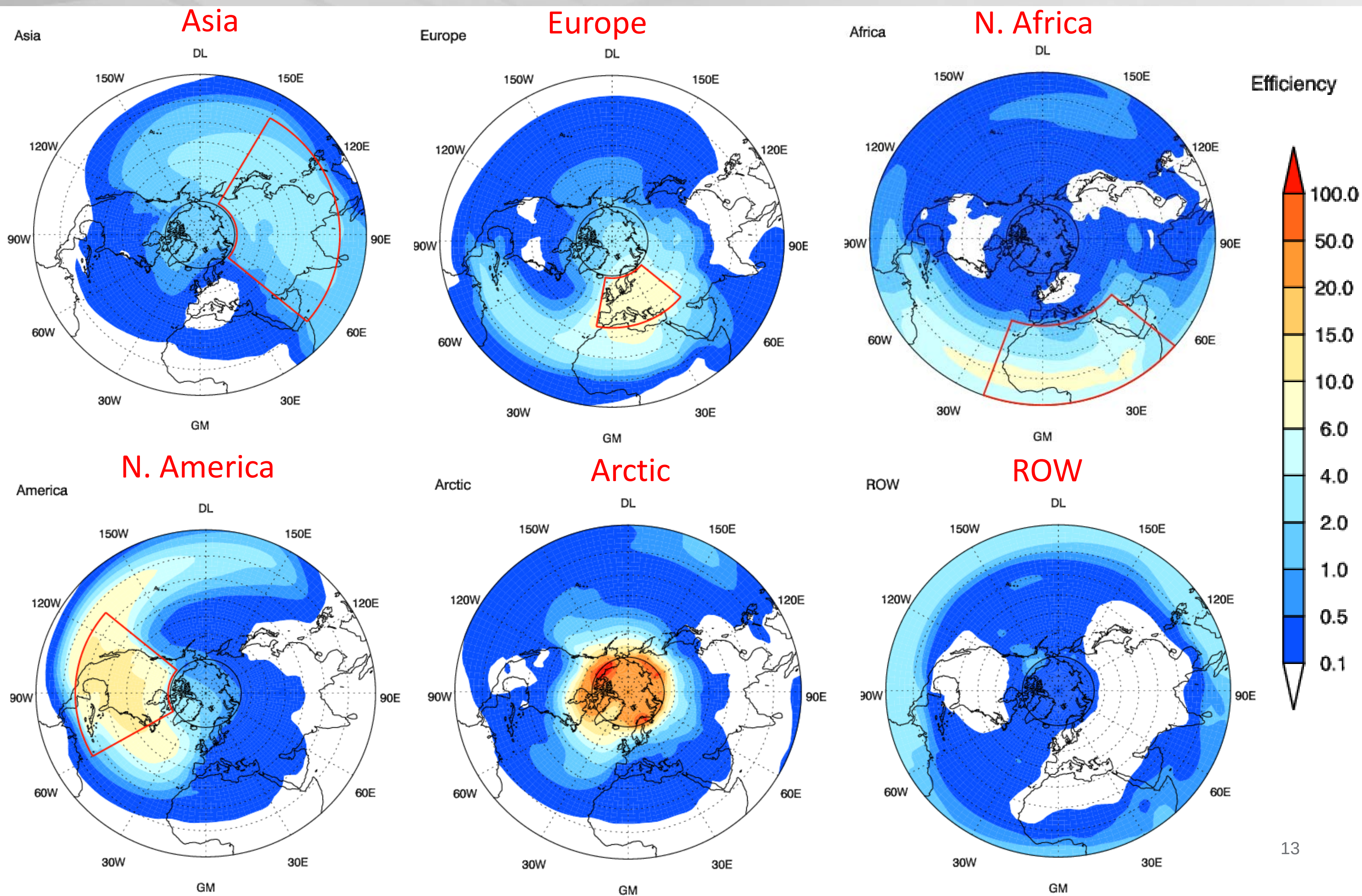
# Arctic BC: seasonal variation of contributions





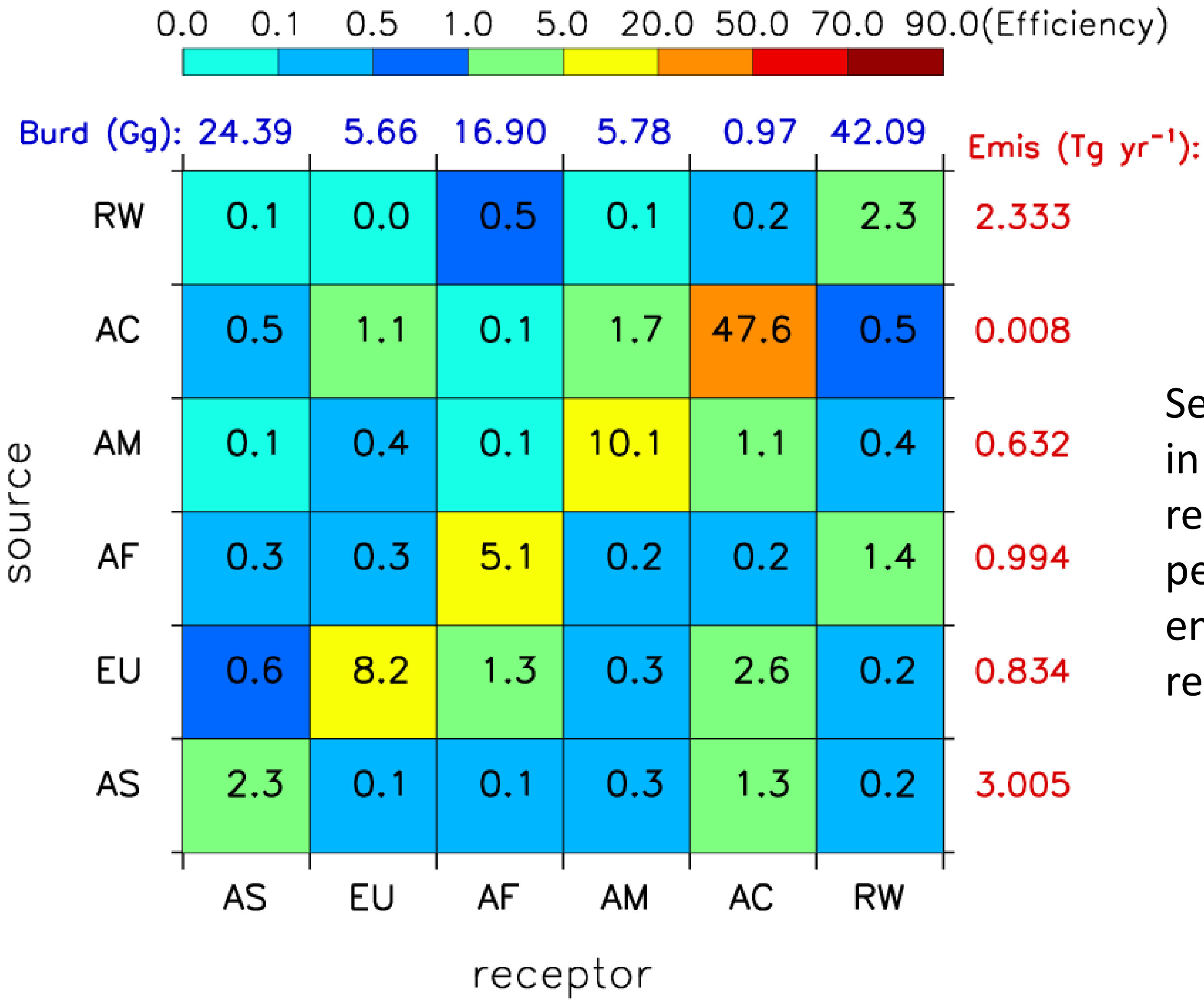
# A different measure: the efficiency





# Results: source/receptor matrix for efficiency






Sensitivity of burden in the receptor region to per unit perturbation of emission in a source region

# Summary



- We developed a regional aerosol source tagging technique in CAM5, which can be used to establish the quantitative aerosol source-receptor relationships and identify transport pathways.
- In this particular study, it's applied to a model version with improved aerosol vertical and long-range transport to focus on Arctic BC.
- Under the AR5 yr2000 emission scenario, emission from Asia contributes the most to the Arctic BC, and then Europe and N. America; they affect different sectors in the Arctic.
- The Arctic BC is most sensitive to emission uncertainties within the Arctic, and then Europe, Asia and N. America.
- We are using this tool to study the impact of changes in regional BC emissions, as well as other aerosol species.