# Intercomparison of iron in AEROCOM models

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# Motivation

Environmental Science & Technology
Critical Review
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**Atmospheric Transport and Deposition of Mineral Dust to the Ocean: Implications for Research Needs**

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- Bio-available iron can stimulate marine productivity when it is a limiting nutrient
- The influence of iron deposition on the carbon cycle has been so far poorly evaluated as several important factors have not been accounted. To progress in that direction we have prepared for an AEROCOM intercomparison by:

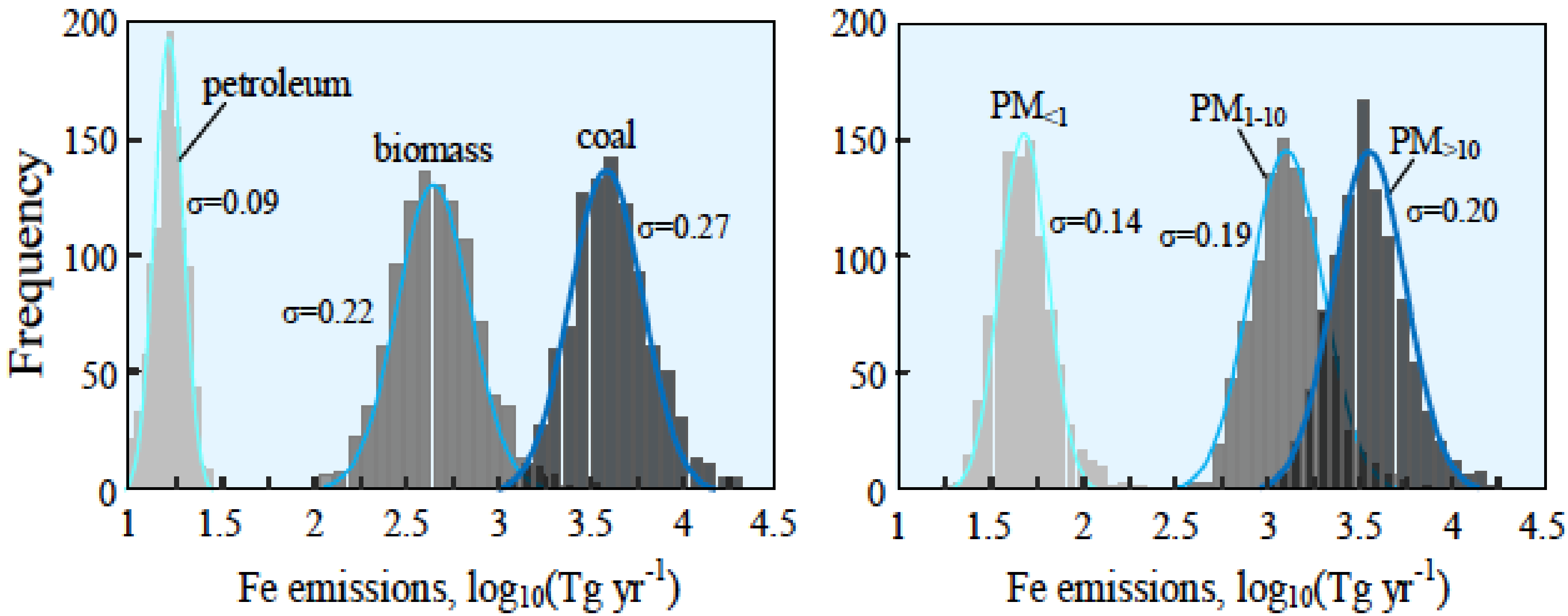
- 1/ Formulating a detailed combustion source for iron
- 2/ Using the published mineralogy from Journet et al. (2004)
- 3/ Assembling together many measurements from the litterature that cover all regions.

# Emission of iron from combustion

$$E = a \cdot b \cdot c \cdot (1 - f) \cdot \sum_{x=1} J_x \cdot \left[ \sum_{y=1}^{4} A_y \cdot (1 - R_{x,y}) \right]$$

*a*: Fuel consumption
*b*: Combustion rate
*c:* fraction of Fe in fuel
*f:* fraction of Fe retained in the residue ash
$J_x$: fraction of Fe emitted in particle size x,
$A_y$: fraction of a given type of control device,
$R_{x,y:}$: removing efficiency of the control device

# Frequency distribution of emissions and particle sizes

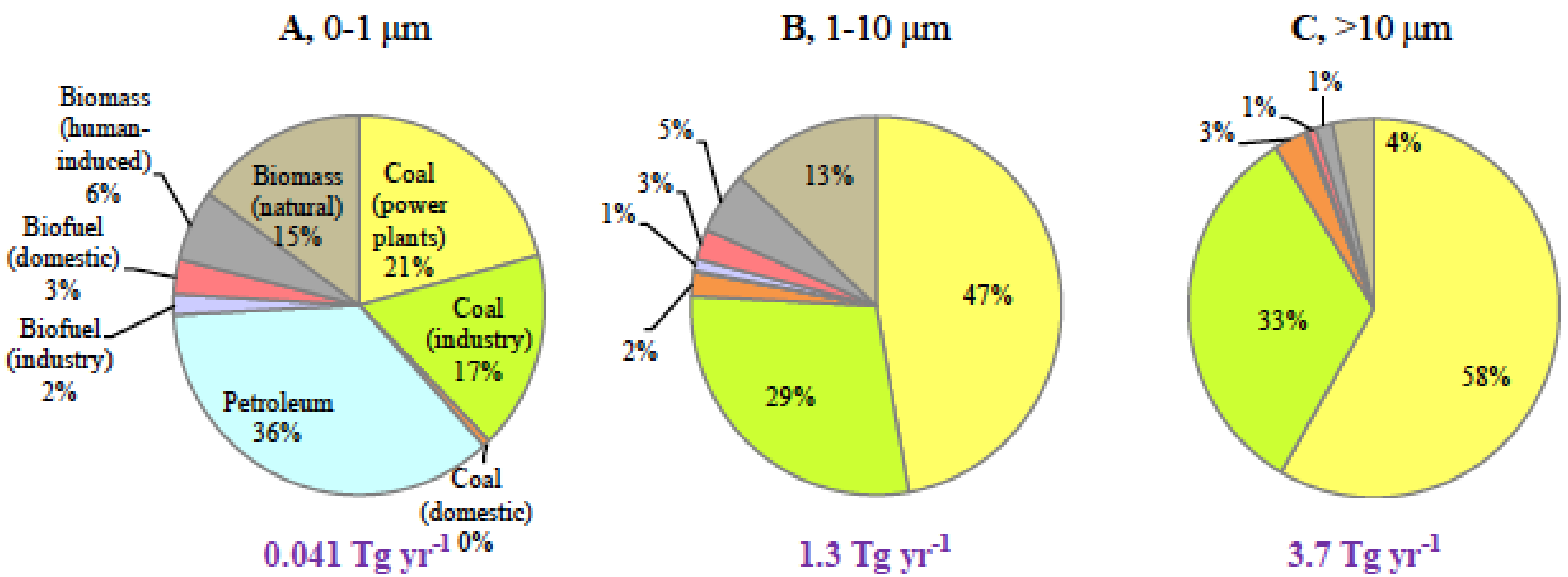



| | |
|---|---|
| from Petroleum: | 0.041 Tg yr-1 |
| From Biomass burning: | 1.32 Tg yr-1 |
| From Coal: | 3.2 Tg y-1 |
| TOTAL: | 5.1 Tg y-1 |

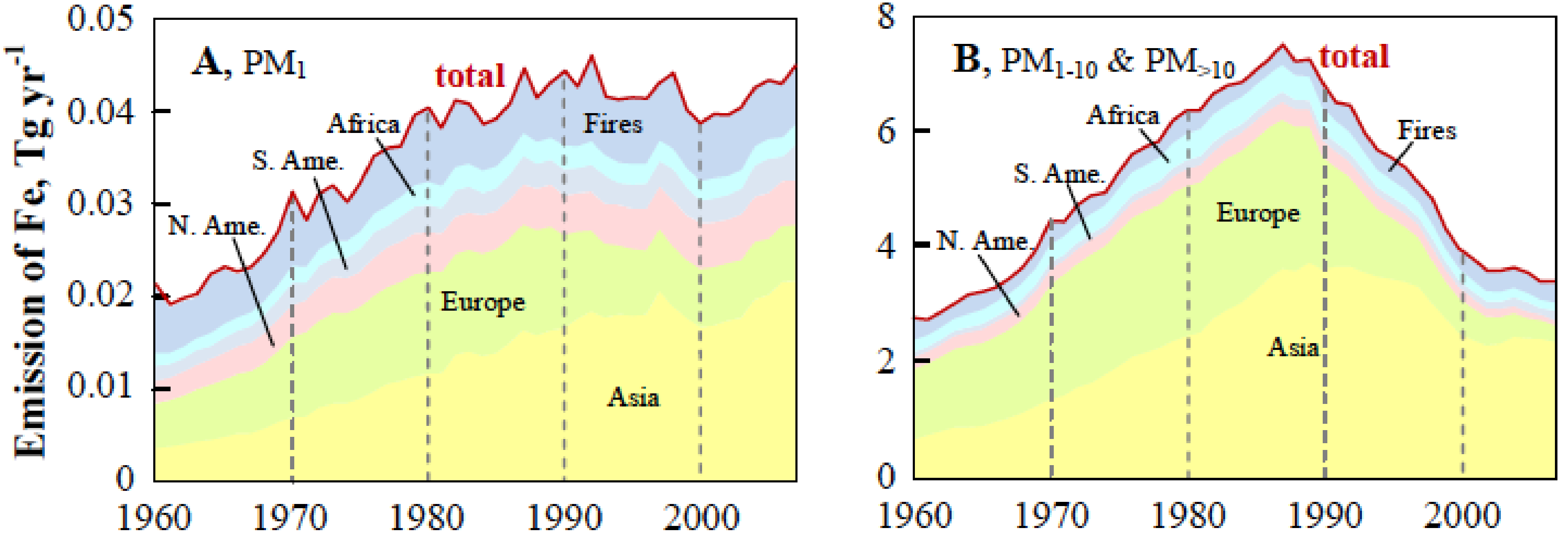
| | | | |
|---|---|---|---|
| Mode 1: | 0.34 um, | $\sigma$=1.59 | 2% |
| Mode 2: | 3.4 um, | $\sigma$=2.0 | 33% |
| Mode 3 | 34 um, | $\sigma$=2.0 | 65% |

Monte Carlo simulations **90% confidence interval** for total emissions: **2.24 – 11.52** around the average value of 5.1 Tg yr-1 for 1960-2007

# Contribution of the different combustion sources to the 3 modes



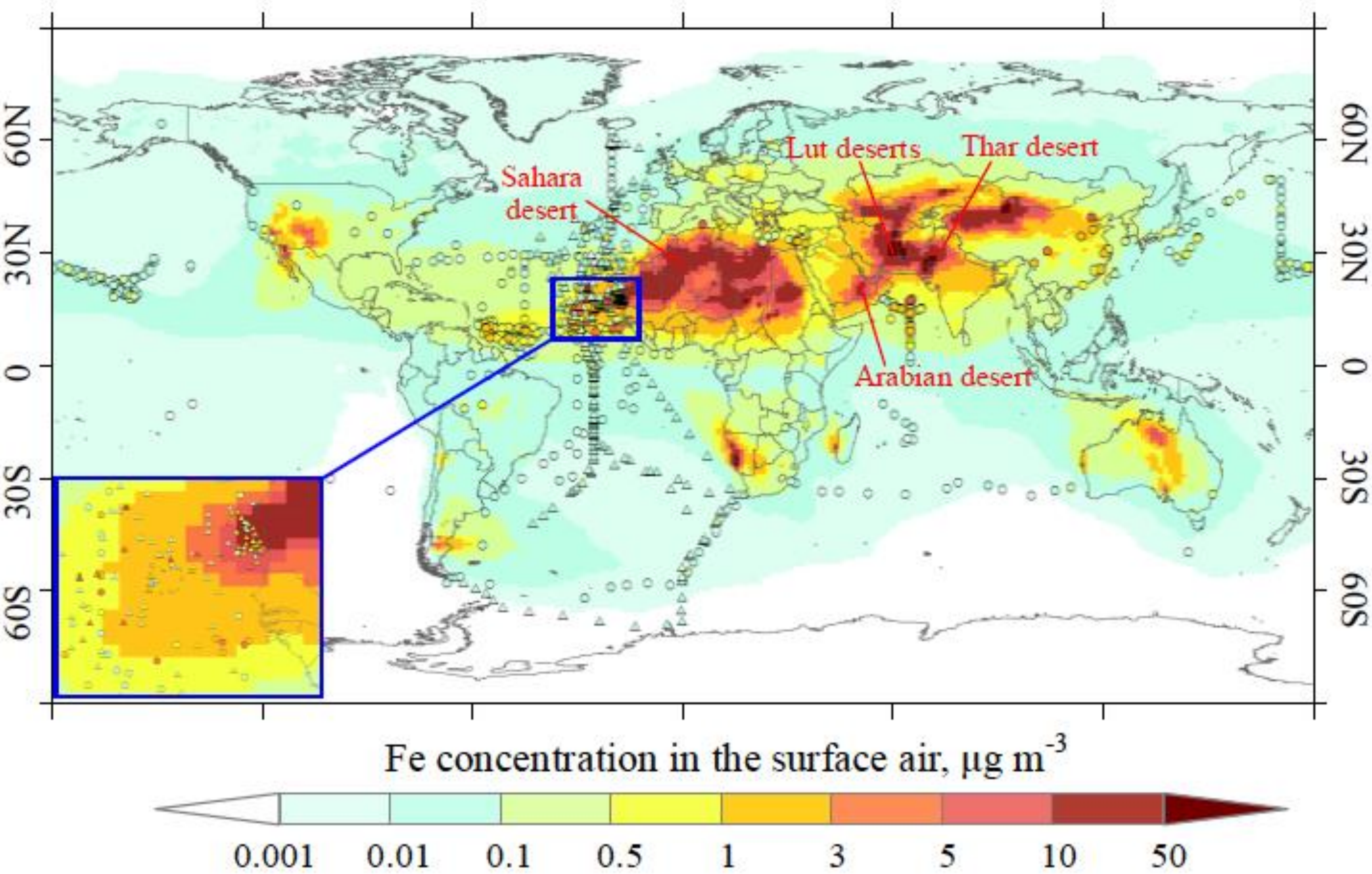
# Historical emissions of Fe in fine particles (PM1) and coarse (PM1-10 plus PM>10) particles from 1960 to 2010



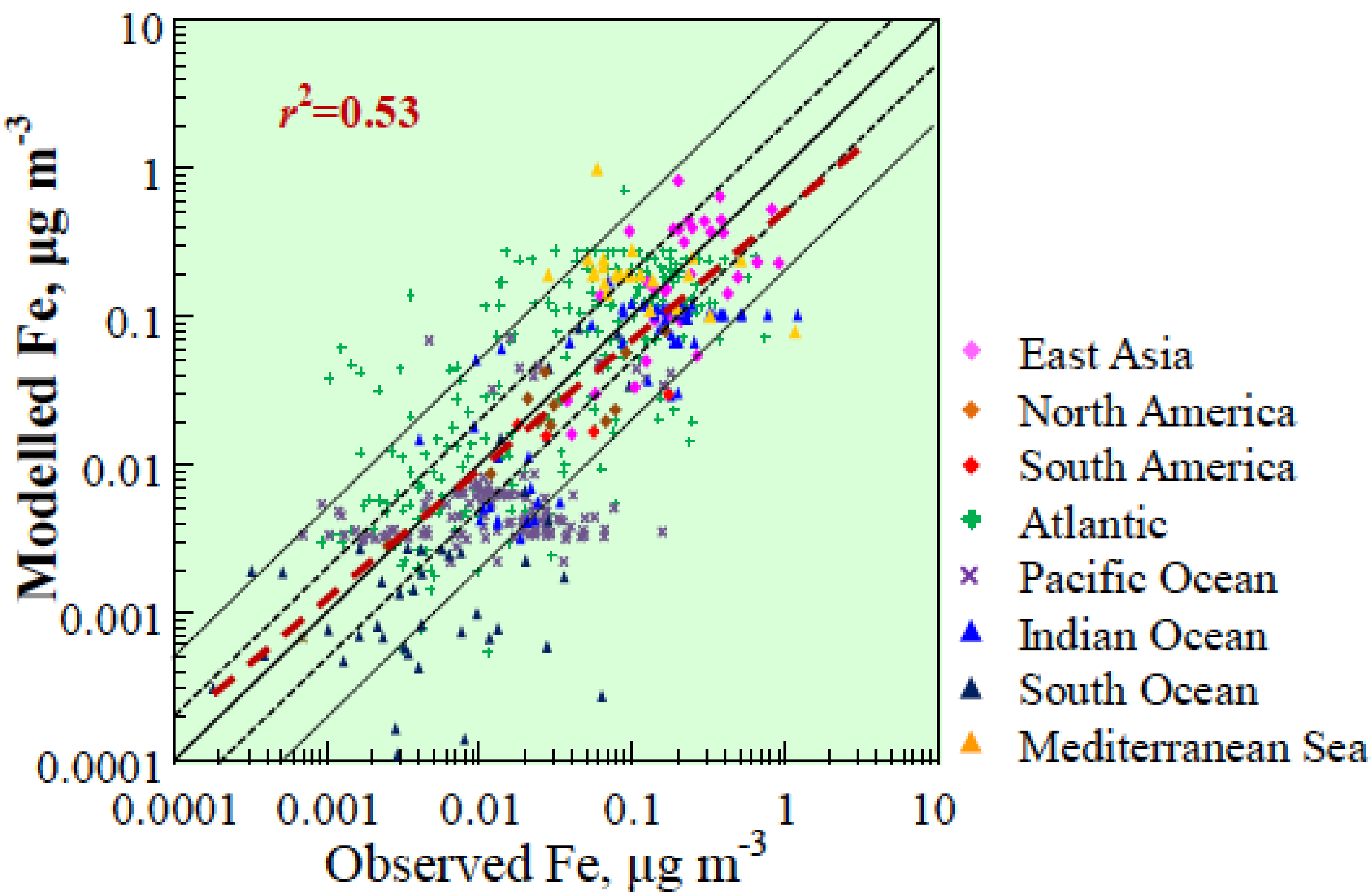
# Comparison with published estimates

| | Years | Fossil fuels | Biomass | Dust |
|---|---|---|---|---|
| **B71** | 1967 | 1.4 (all sizes) | | |
| **Luo08** | 1996 | 0.56 ($PM_{1\text{-}10}$) | 0.86 ($PM_{1\text{-}10}$) | 55 (using a Fe content of 3.5%) |
| | | 0.10 ($PM_1$) | 0.21 ($PM_1$) | |
| **Ito13** | 2001 | 0.44 ($PM_{1\text{-}10}$) | 0.92 ($PM_{1\text{-}10}$) | 74 (using a Fe content of 3.5%) |
| | | 0.07 ($PM_1$) | 0.23 ($PM_1$) | |
| **Our work** | 1967 | 2.32 ($PM_{>10}$) | | |
| | | 0.64 ($PM_{1\text{-}10}$) | | |
| | | 0.017 ($PM_1$) | | |
| | 1996 | 1.14 ($PM_{1\text{-}10}$) | 0.31 ($PM_{1\text{-}10}$) | |
| | | 0.036 ($PM_1$) | 0.012 ($PM_1$) | |
| | 2001 | 0.83 ($PM_{1\text{-}10}$) | 0.31 ($PM_{1\text{-}10}$) | |
| | | 0.035 ($PM_{1\text{-}10}$) | 0.012 ($PM_1$) | |
| | 2007 | | | 35 (using a Fe content of 3.5%) |
| | 2007 | | | 38 (using the mineralogy data) |

# Annual mean concentrations of Fe in the surface air.at 529 sites + 296 from cruises over the Atlantic (A. Baker)



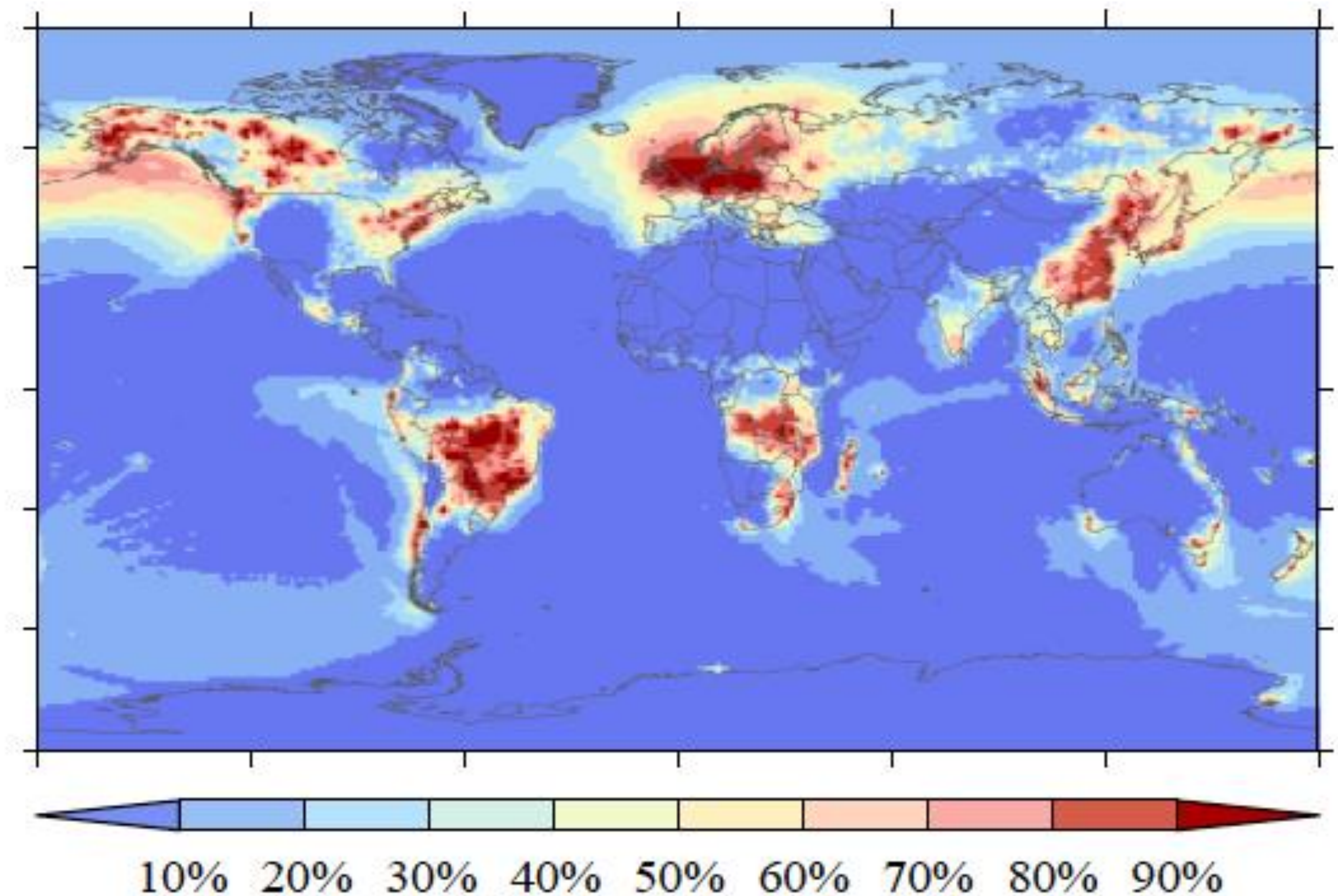
# Comparison of modelled versus measured atmospheric Fe concentrations



# Statistics of the comparison by region

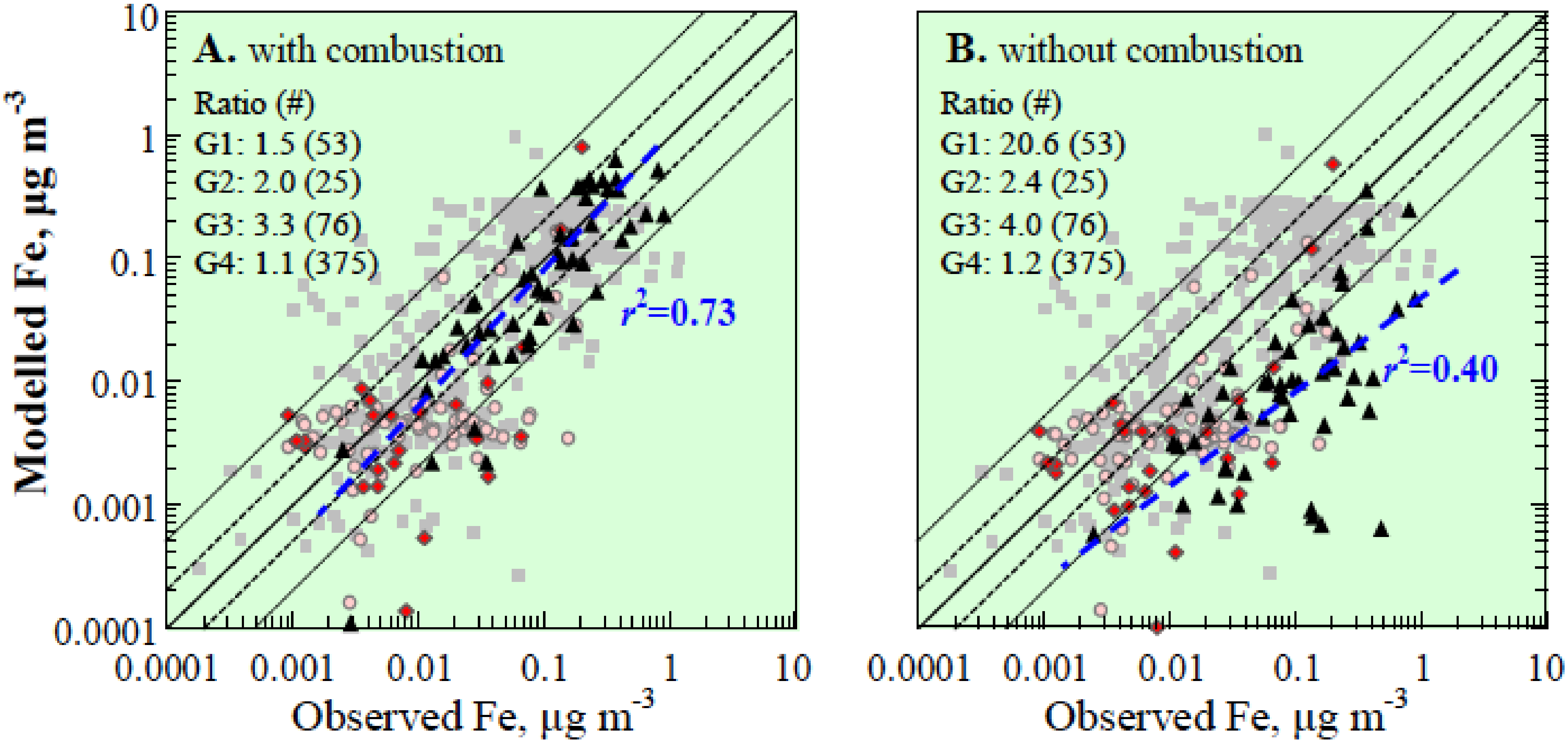
| | N | $F_2$ | $F_5$ | NMB |
|---|---|---|---|---|
| Indian Ocean | 61 | 30% | 75% | –67.9% |
| Atlantic Ocean | 224 | 64% | 82% | 15.1% |
| Pacific Ocean | 126 | 52% | 69% | –66.2% |
| South Ocean | 47 | 43% | 53% | –47.7% |
| East Asia | 32 | 84% | 100% | –2.1% |
| South Ame. | 4 | 50% | 75% | –78.2% |
| North Ame. | 12 | 83% | 100% | –40.3% |
| Mediterranean | 23 | 61% | 87% | 24.4% |
| **All regions** | **529** | **57%** | **77%** | **–14.2%** |

# Relative importance of combustion sources to total iron atmospheric concrentrations

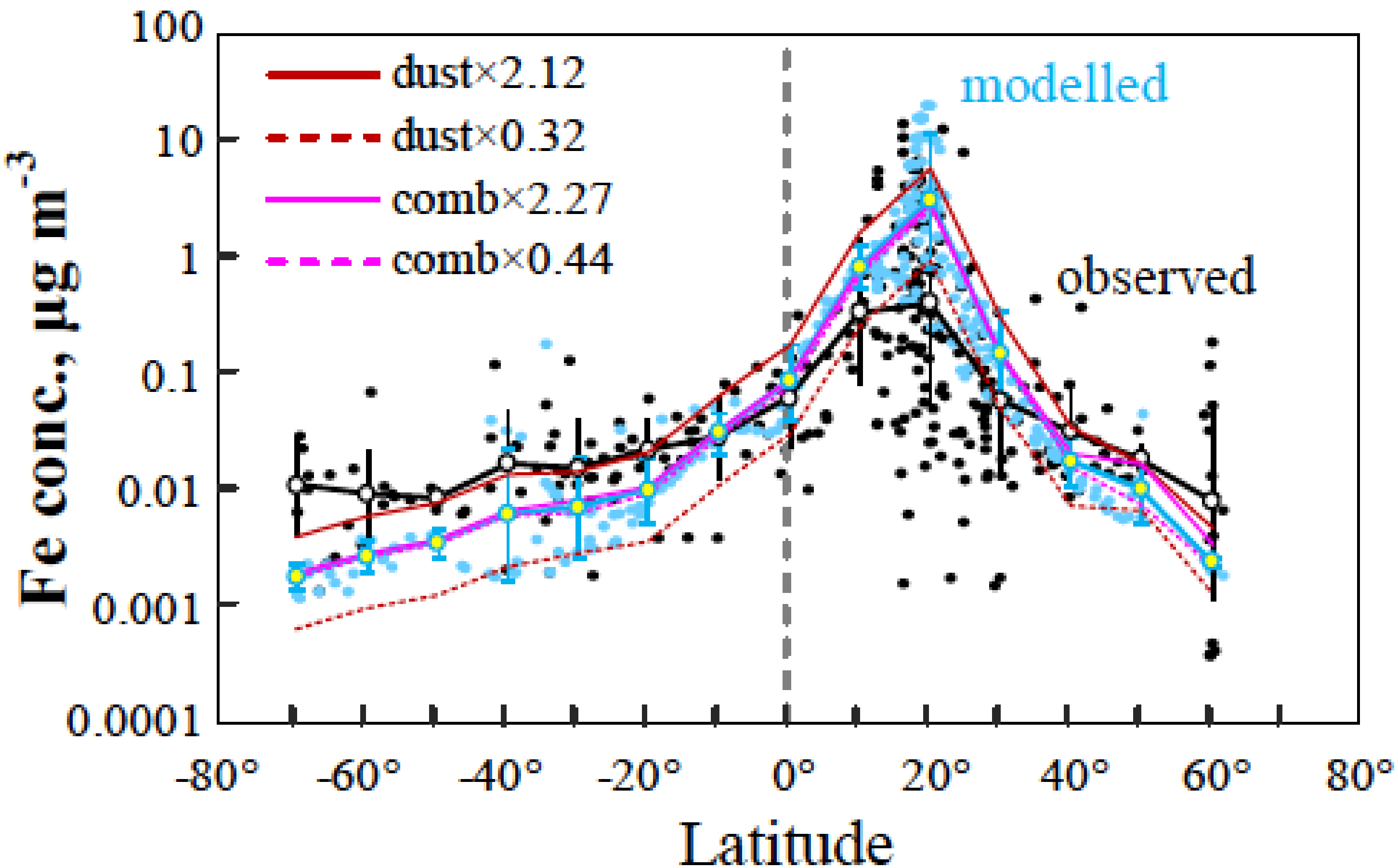


# Modelled and observed Fe concentrations for different contributions from combustion sources.

G1: contribution > 50%;   G2 > 30%;   G3 > 15%;  G4 < 15%



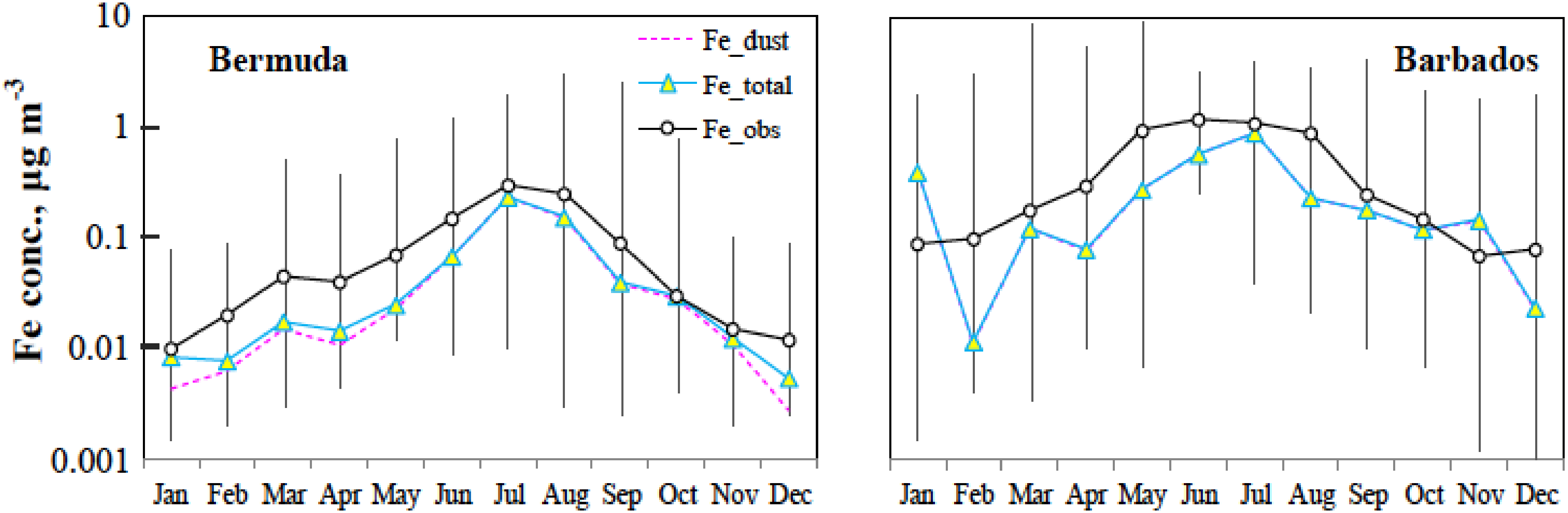
# Distribution of the modelled (blue) and observed (black) Fe concentrations in the surface air over the Atlantic Ocean from 70°S to 60°



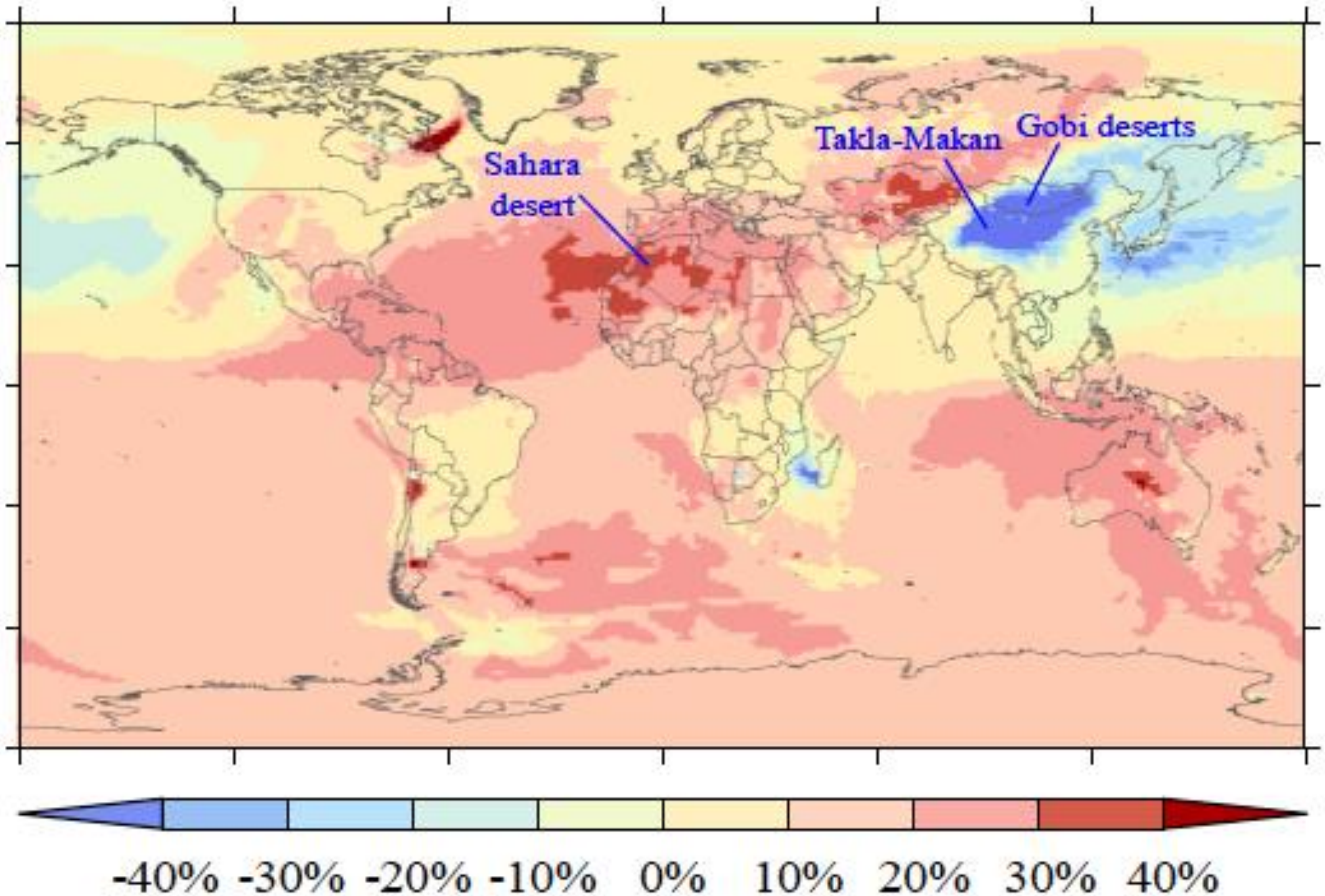

Scaling for dust source and combustion source encompasses 90% uncertainty

# Seasonality in the iron surface concentrations at Bermuda and Barbados

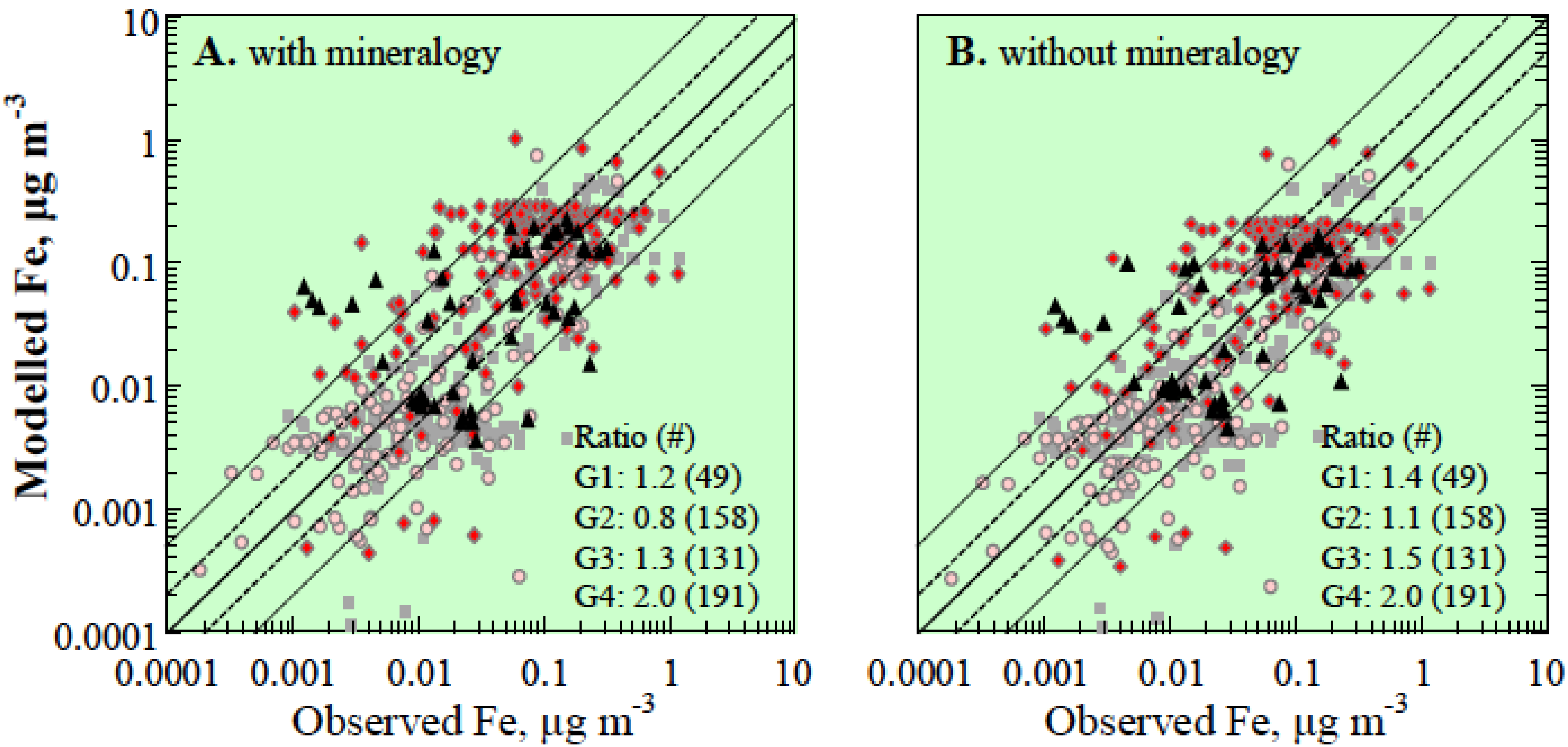
(32.2°N, 64.5°W) (13.2°N, 59.3°W)



# Change in iron concentrations when accounting for the mineralogy of dust (compared to constant 3.5% iron content in dust)



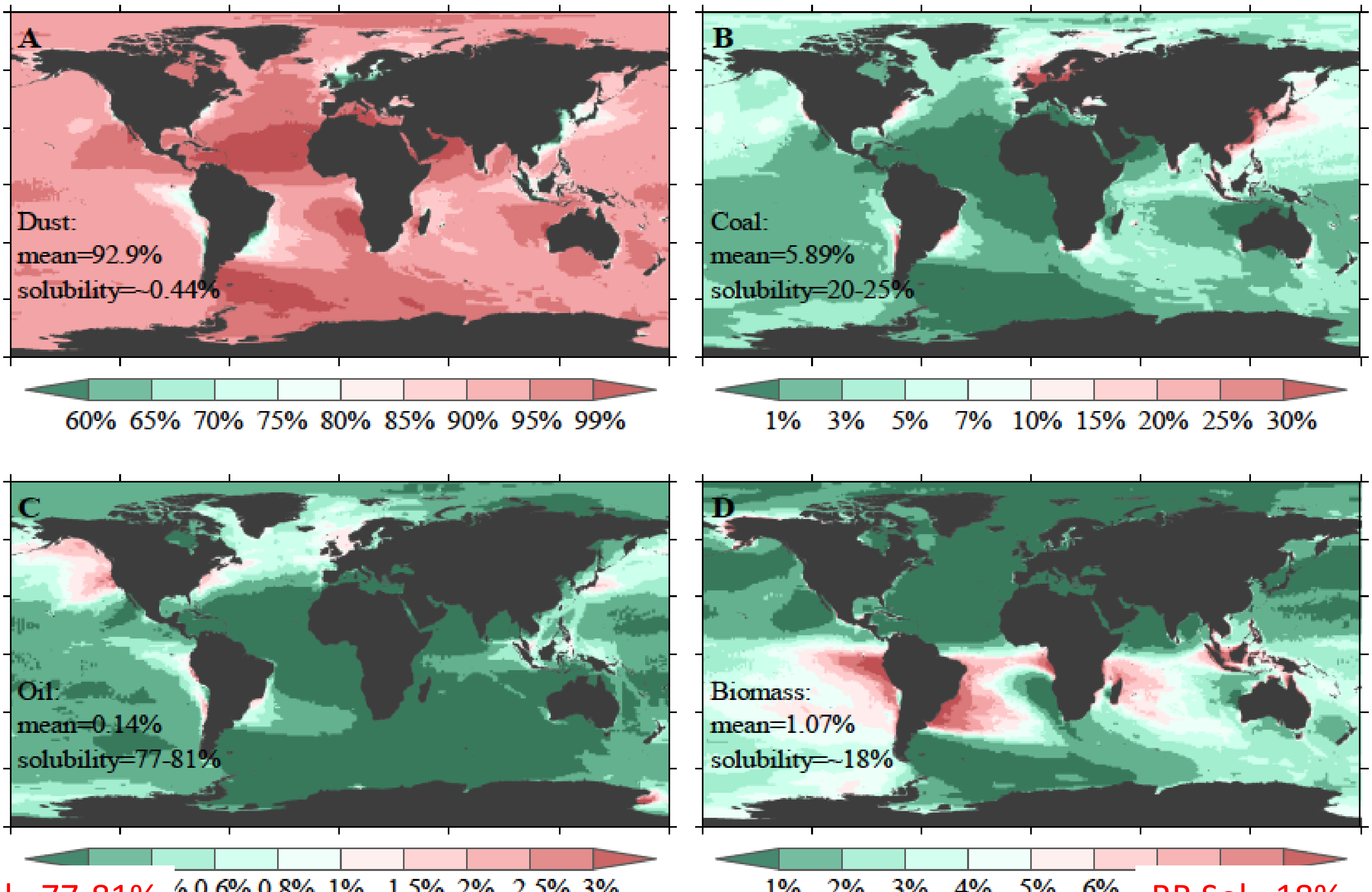
Plot of the modelled and observed Fe concentrations at sites with different influences by using the new mineralogical data from Journet et al., 2014.



# Contribution to total Fe deposition over oceans from different sources. 7.7 Tg yr-1 deposited over oceans of which 7% comes from combustion sources

Dust Sol=0.44%

Coal Sol=20-25%




Oil Sol= 77-81%

BB Sol= 18%

# AEROCOM Iron Experiment

- EXP 1: assume iron represents 3.5% of dust mass
- EXP 2: based upon the mineralogy we provide, iron concentration and deposition will be compared to measurements by regions
- EXP 3: Effect of the combustion source
- EXP4: Compute the soluble iron with the best assumptions taken from your chemical model
- … Analyze the processes that form the soluble iron (pH, mineralogy, other processing…)

# Timeline for this activity
(contact me if you want to co-lead it!)

- JAN 2015: Protocol will be distributed
- JUNE 2015 First serie of 4 experiments
- Present the results at the next AEROCOM meeting in Rome.