Combining CERES Observations and GOCART Simulations to Derive Component Aerosol Direct Radiative Effect/Forcing (DRE/DRF) at the Top of Atmosphere for the Clear Sky over Global Oceans

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Outline

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- ✓ Methodology & Results
- ✓ Summary & Conclusion
- ✓ Acknowledgement

Background & Objective

- **Background:**
  - Satellite observations have actively joined traditional model calculations for estimation of global Aerosol DRE.
  - Observed size information has also been used to discriminate ensemble anthropogenic aerosol from natural aerosol.
  - It is still difficult to use satellite observations alone to discriminate aerosols into more detailed components over the globe as well as to derive their DRE/DRF.

- **Objective:**
  - To derive component aerosol DRE/DRF over global oceans by combining CERES/SSF data and GOCART model simulations for Sea Salt (SS), Dust (DU), Sulfate (SU), Organic Matter (OM), and Black Carbon (BC).

CERES and GOCART Products

- **CERES Observations:**
  - Edition-1A Terra/CERES-MODIS SSF Data for the year 2001 (Jan., April, July, Oct.)
  - CERES/MODIS SSF aerosol optical thickness (AOT or τ) at 0.55-μm, TOA SW fluxes, and CERES clear strong index (CSI).
  - Fill the gapes of MODIS $\tau_{0.55}$ with the GOCART $\tau_{0.55}$ using an optimum interpolation approach with the Kalman-Bucy filter (see Yu et al., 2003).

- **GOCART Simulations:**
  - GOCART classification: SS, DU, SU, OM, and BC (Aerosols externally mixed)
  - Daily component aerosol optical thickness at 0.55-μm (τ_{SS},τ_{DU},τ_{SU},τ_{OM},τ_{BC}, τ_{TOT}) for the year 2001.
  - Anthropogenic (A) component ($\tau_A=\tau_{SU}+\tau_{OM}+\tau_{BC}$) and natural (N) component ($\tau_N=\tau_{SS}+\tau_{DU}$).
  - Partitioning factors of component AOT $r_i=\tau_i/\tau_{TOT}$($\tau_i=\tau_{SS}$, τ_{DU}, τ_{SU}, τ_{OM}, τ_{BC}, τ_A, τ_N).

Methodology

- Step 1: Derive aerosol DRE at TOA (see Loeb & Kato, 2002):

  $\Delta F(d,\theta,\phi)=F_{na}(d,\theta,\phi) - F_a(d,\theta,\phi)$

  $F_a(d,\theta,\phi)$: daily average SSF SW fluxes in presence of aerosols (CSI ≥ 99%).

  $F_{na}(d,\theta,\phi)$: daily average SW fluxes in absence of aerosols derived through regression of merged $\tau_{0.55}$ versus SSF TOA clear-sky SW fluxes in 1° solar zenith angle increments and extrapolated to zero AOT.

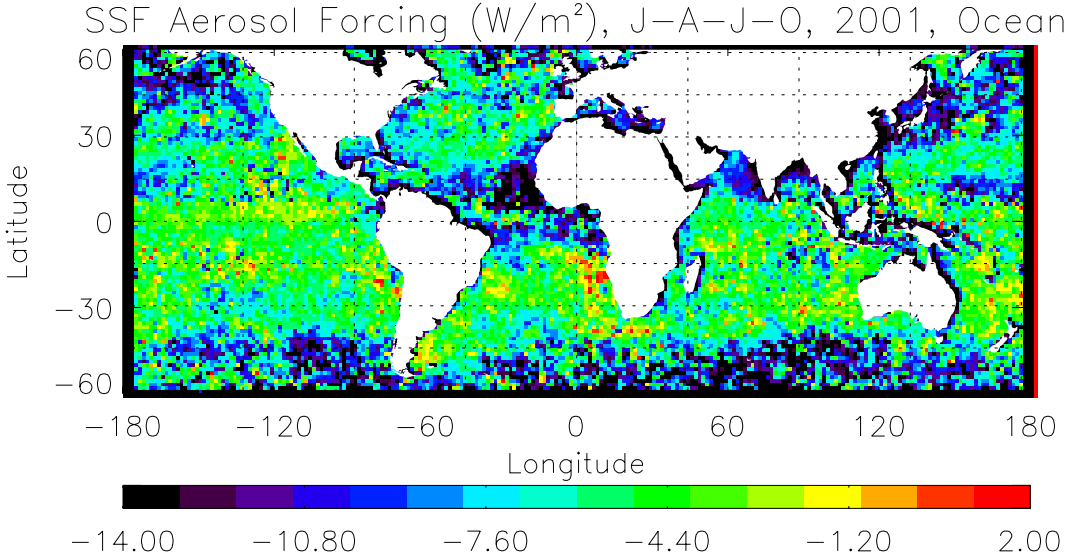
- Step 2: Partition ΔF for component aerosols ΔF_i (i=N, A, SS, DU, SU, OM, BC):
  - $\Delta F \sim (e^{-\tau}-1)$ for non- or weak absorbing aerosols (Boucher et al, 1998; Boucher and Tanre 2000).
  - $\Delta F_N = \Delta F \times (e^{-\tau N}-1)/(e^{-\tau TOT}-1)$ (assuming total ensemble aerosol forcing efficiency is close to that of non- and weak absorbing aerosols)

    $\Delta F_A = \Delta F - \Delta F_N$
  - $\Delta F_i = \Delta F \times (e^{-\tau i}-1)/(e^{-\tau TOT}-1)$ (i=SS, DU, SU, OM)

    $\Delta F_{BC} = \Delta F - \sum_{i=1}^{4} \Delta F_i$

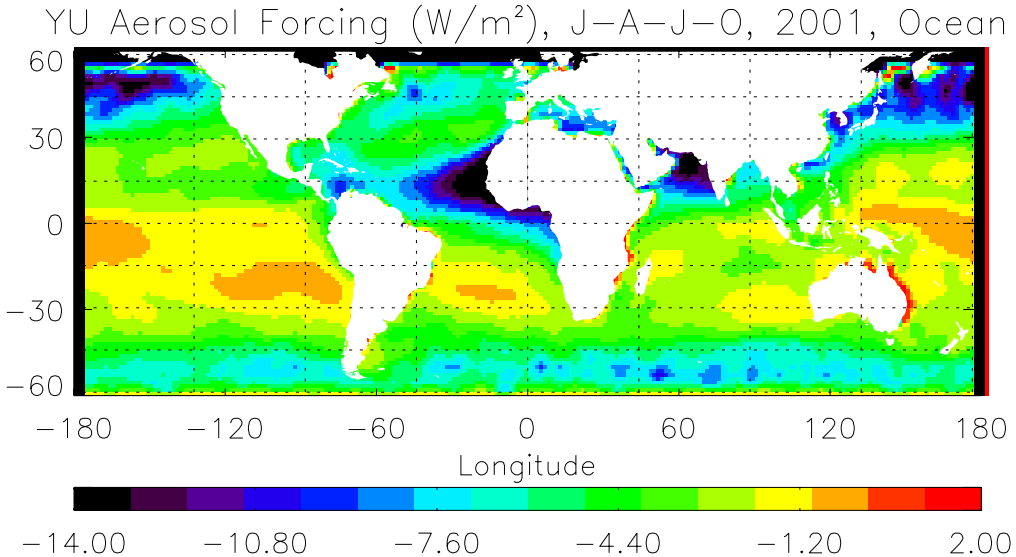
Results
(4-month Average of Aerosol DRE at TOA)

Satellite (CERES)



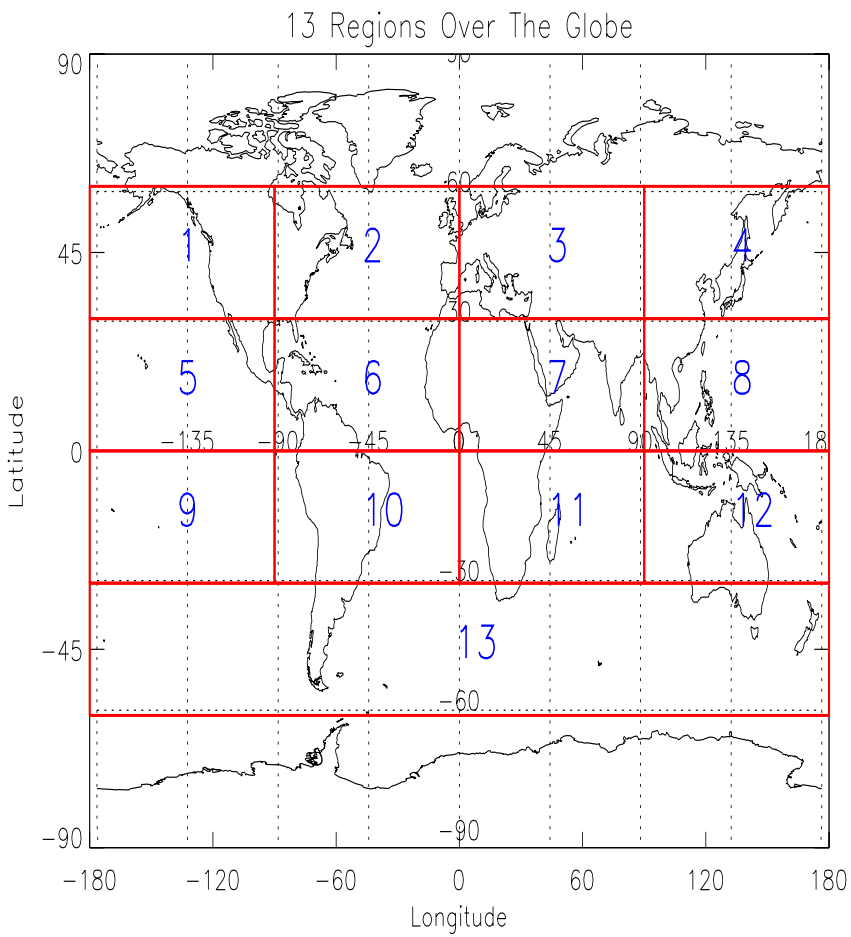
ΔF=-6.47 (W/m^2)

Model (Fu-Liou)



ΔF=-5.14 (W/m^2)

Regional Comparison



Regions	SSF (W/m^2)		Model (W/m^2)		Difference $\lvert\Delta F_S - \Delta F_M\rvert$
	ΔF_S	STD	ΔF_M	STD	
1	-7.992	3.974	-7.087	3.547	0.905
2	-7.129	3.717	-6.361	2.984	0.768
3	-7.359	3.813	-5.832	3.334	1.526
4	-7.695	3.989	-6.421	3.503	1.275
5	-6.858	3.786	-5.777	3.140	1.081
6	-7.161	3.954	-6.194	3.253	0.967
7	-7.301	4.006	-6.115	3.424	1.186
8	-7.196	3.971	-5.854	3.283	1.342
9	-6.727	3.825	-5.408	3.210	1.318
10	-6.585	3.786	-5.226	3.145	1.360
11	-6.412	3.768	-5.091	3.052	1.321
12	-6.259	3.753	-4.909	2.979	1.350
13	-6.386	3.810	-5.140	2.684	1.246

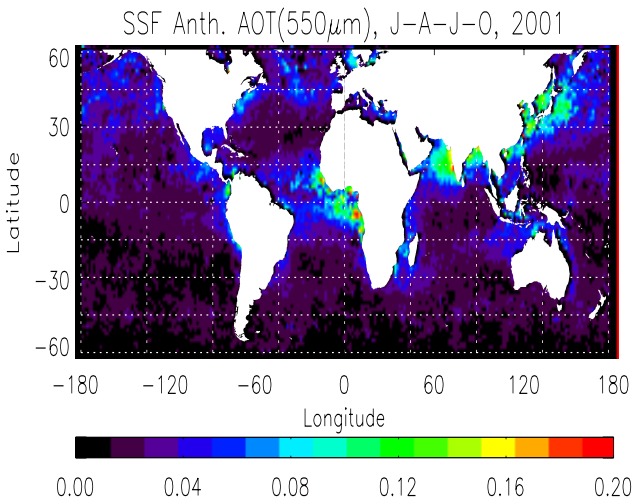
Suggested by CCSP Working Group

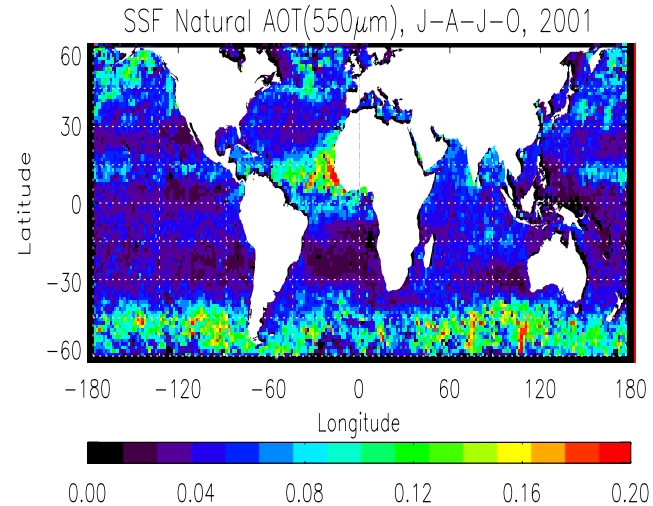
Aerosol DRE/DRF of Natural and Anthropogenic Components

Anthropogenic

Natural

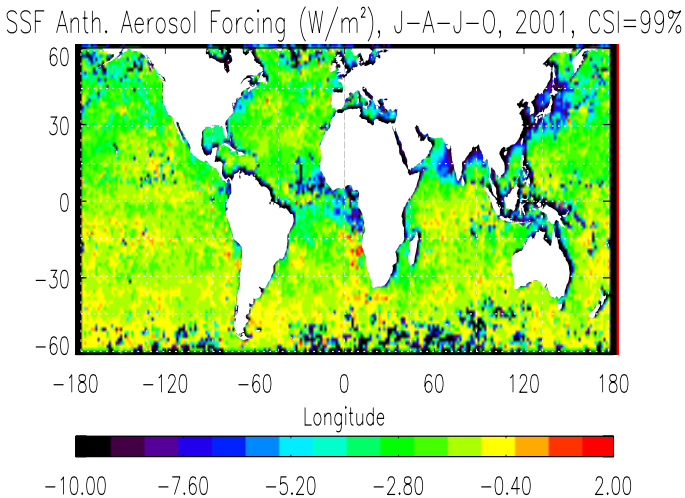
τ=0.029

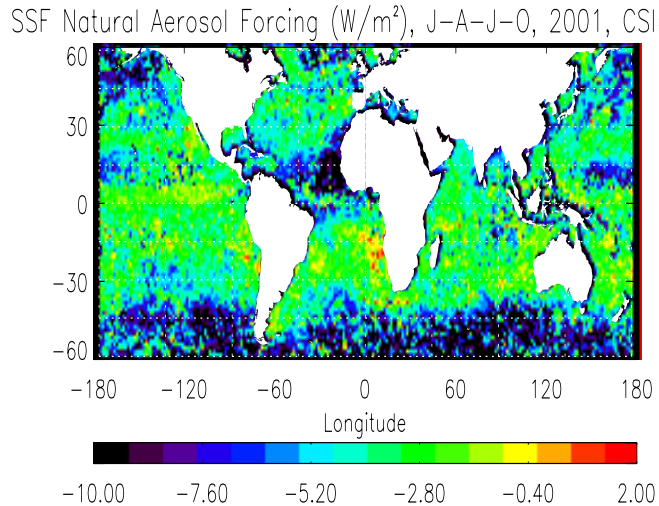




τ=0.061

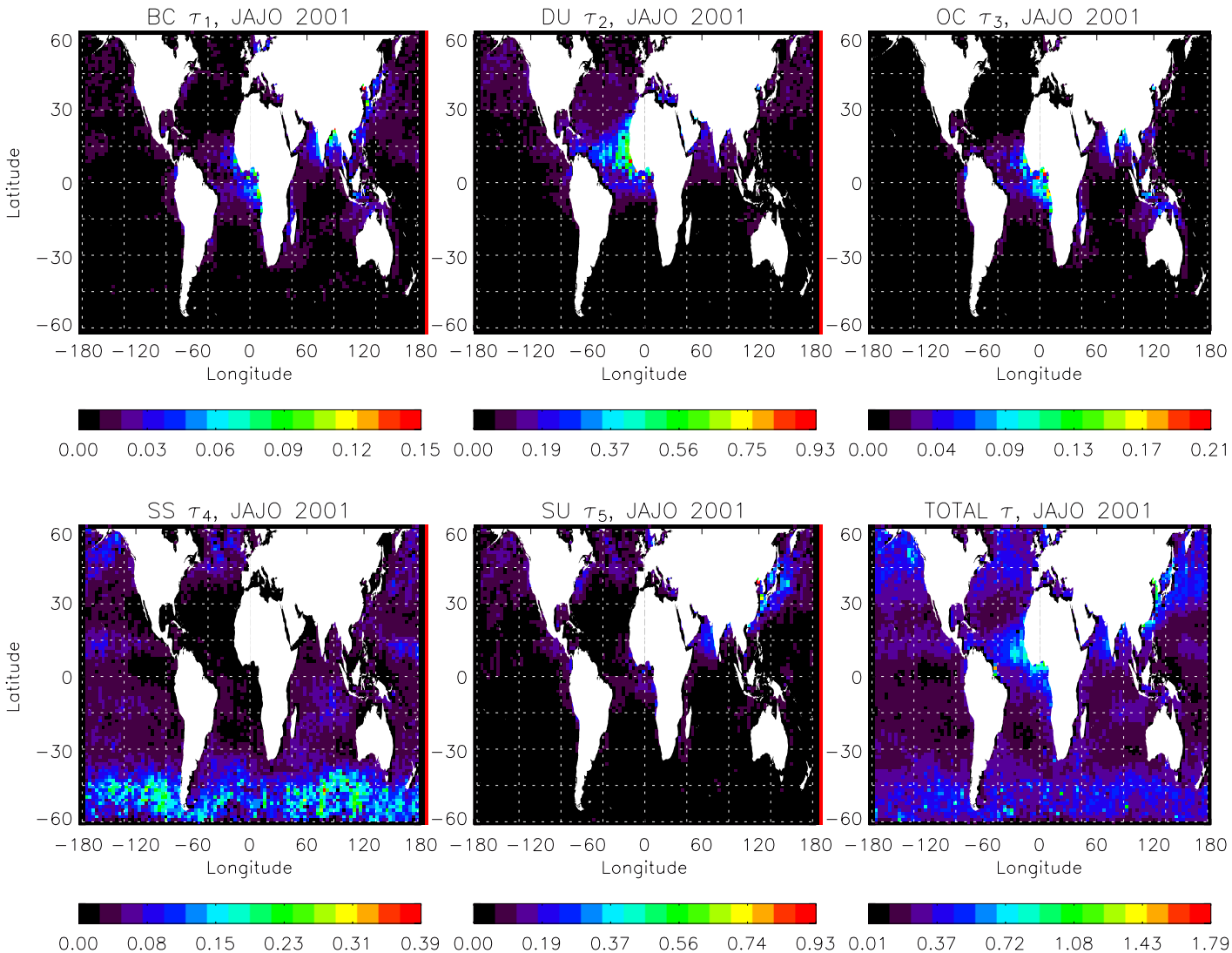
ΔF=-2.03 (W/m^2)





ΔF=-4.44 (W/m^2)

Component Aerosol Optical Thickness

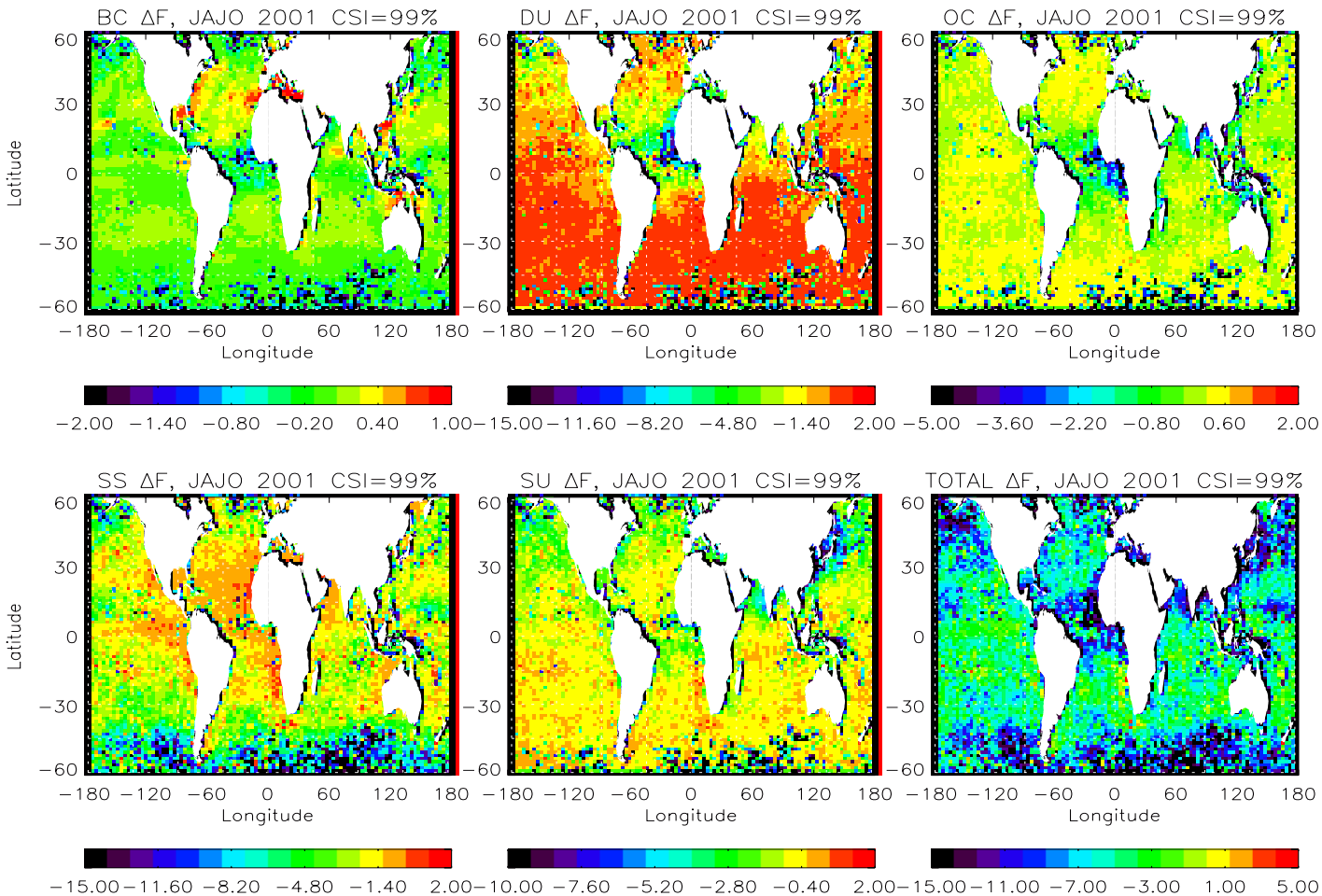


Aerosol DRE/DRF of Major Components

Black Carbon
ΔF=+0.05

Dust
ΔF=-1.42

Organic Carbon
ΔF=-0.53



ΔF=-3.06
Sea Salt

ΔF=-1.40
Sulfate

ΔF=-6.47
Total

Comparison with Other Observations and Models

AC	ΔF (W/m^2)			
	This Work	[1]GCM	[2]Recent Observations	[3]Recent Models
BC	+0.05	+0.17	—	+0.15 — +0.45
OM	-0.53	-1.02	—	-0.15 — -0.65
SU	-1.40	-1.65	—	-0.21 — -0.96
DU	-1.42	-1.12	-0.8	—
SS	-3.06	-3.27	-5.1	—
AN	-2.03	-2.10	-0.9	—
NA	-4.44	-4.75	-5.9	—
Total	-6.47	-6.85	-3.8 — -7.1 (-5.5)	-2.3 — -4.7 (-3.2)

[1]GCM values are taken from Haywood et al. [1999].
[2]Recent observational values are taken from Yu et al. [2005].
[3]Recent modeling values are mainly based on Yu et al. [2005] for total forcing and Schulz et al. [2005]

Summary and Conclusions

- ✓ A two-step approach is proposed for deriving component aerosol DRE/DRF at TOA over global oceans for clear-sky conditions by combining Terra/CERES-SSF data with the GOCART model simulations.
- ✓ The derived annual mean aerosol DRE/DRF over global oceans is -6.47 W/m^2 for total aerosols, -4.44 W/m^2 for natural component, -2.03 W/m^2 for anthropogenic component, -3.06 W/m^2 for sea salt, -1.42 W/m^2 for dust, -1.40 W/m^2 for sulfate, -0.53 W/m^2 for organic matters, and +0.05 W/m^2 for black carbon.
- ✓ The major error resulted from the proposed approach is in the estimation of aerosol forcing of strong absorbing black carbon component. Moderate error for organic matters is also expected. Cloud contamination and regression estimation of Fna are two major error sources for the estimation of total aerosol DRE.

Acknowledgements

- ✓ Founding support from the NASA Radiation Program.
- ✓ Supply of the CERES/SSF data by the NASA CERES Project and the DAAC of the NASA Langley.

Backup Slides

Annual Mean TOA Aerosol DRE/DRF for the Major Aerosol Components

Aerosol Type	$\overline{\Delta F}$ (w/m^2)		
	Global	NH	SH
OC	-0.53	-0.61	-0.45
BC	+0.05	0.09	0.02
Sulfate (SU)	-1.40	-2.21	-0.92
Dust (DU)	-1.42	-2.36	-0.72
Sea Salt (SS)	-3.06	-2.28	-3.68
Natural Aerosol (DU, SS)	-4.44	-4.58	-4.38
Anthropogenic Aerosol (OC, BC, SU)	-2.03	-2.97	-1.42
Total	-6.47	-7.55	-5.80

Note: The values are actually obtained by averaging the results of January, April, July, and, October (J-A-J-O) of 2001.

Estimation of Global and Annual Mean Uncertainties

- **Total Forcing:**
  - Uncertainty in F_{na} derivation (~15%)
  - Cloud Contamination (~5%)

- **Component Forcing:**
  - Uncertainty in Partitioning
    - NA (~5%)
    - AN (~5%)
    - SS (~4%)
    - SU (~4%)
    - DU (~10%)
    - OC (~15%)
    - BC (~33%)

- **Uncertainty in Total Forcing:**
  - ~20%

- **Uncertainty in Component Forcing:**
  - ~25% (NA)
  - ~25% (AN)
  - ~24% (SS)
  - ~24% (SU)
  - ~30% (DU)
  - ~35% (OM)
  - ~53% (BC)

Global mean TOA aerosol DRE/DRF (in W/m^2) of the major aerosol components (AC) and optical thickness (τ).

AC	January		April		July		October		Average	
	ΔF	τ	ΔF	τ	ΔF	τ	ΔF	τ	ΔF	τ
BC	0.15	0.003	0.08	0.005	0.03	0.003	0.07	0.004	0.05	0.003
OC	-0.80	0.009	-0.54	0.009	-0.24	0.006	-0.44	0.009	-0.53	0.007
SU	-1.81	0.021	-1.23	0.022	-0.53	0.016	-1.20	0.018	-1.40	0.018
DU	-1.78	0.015	-1.18	0.021	-0.55	0.027	-1.10	0.017	-1.42	0.019
SS	-4.02	0.045	-2.41	0.040	-0.57	0.028	-2.26	0.038	-3.06	0.042
NA	-5.63	0.060	-3.55	0.061	-1.33	0.055	-3.12	0.055	-4.44	0.061
AA	-2.93	0.032	-1.88	0.035	-0.60	0.025	-1.95	0.031	-2.03	0.029
Total	-8.56	0.152	-5.43	0.175	-1.92	0.161	-5.07	0.162	-6.47	0.160