Model Validation of CCCma\textsuperscript{3} AGCM4

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January Aerosol Mass Burdens (mg/m^2)

- Sulfate
- Total Carbonaceous
- Total Sea Salt
- Total Dust

The maps illustrate the distribution of various aerosol masses across different regions of the world, showing variations in concentration levels.
Sulphur Cycle in AGCM4: Results

$SO_4^\text{=} \text{ burden (in } \mu\text{gS/m}^2\text{)}$

JJA

DJF
Sulphur Cycle in AGCM4: Comparisons With Observations Near Ground

- Chin et al. (1996)
- Prospero and Savoie
- CASTNet (US EPA)
- CAPMoN (Env. Canada)

131 Sites
Sulphur Cycle in AGCM4: Comparisons With Observations Near Ground
Sulphur Cycle in AGCM4: Comparisons With Observations Near Ground

**JJA**

- Model/obs ratio = 0.84
- Correlation = 0.92

**DJF**

- Model/obs ratio = 0.79
- Correlation = 0.78
Sea Salt Aerosol in AGCM4: Results

Sea salt concentration in first model layer (in $\mu$g/kg)

- JJA
- DJF
Sea Salt Aerosol in AGCM4: Comparisons With Observations Near Ground

Data: Prospero and Savoie
Sulphur Cycle in CCCma AGCM4: SO\textsubscript{x} Emissions
January Surface Aerosol Mass Mixing Ratios (kg/kg)
Tracer Transport in AGCM4: Methodology

\[ s = q_0 \left( \frac{1}{1 + p \ln \frac{q_0}{q}} \right)^{1/p} \]

\[ s = q \]

for \( q \leq q_0 \)

for \( q > q_0 \)

Options for tracer advection in AGCM4:
* Spectral
* Semi-Lagrangian
Tracer Transport in AGCM4: Idealized Tests

Courtesy W. Merryfield
Sea Salt Aerosol in AGCM4: Parameterization of Mass Size Distribution

NaCl size distribution in marine boundary layer

Obs: JASIN experiment (Fairall et al., 1983)
Parameterization of Convection: Basic Equations

\[ \frac{\partial \rho}{\partial t} = -\frac{\partial}{\partial z} (\rho a w_c) + E - D \]

\[
\rho \frac{\partial}{\partial t} (a \chi_c) = -\frac{\partial}{\partial z} \left(\rho a \bar{w} \chi_c^c\right) + E \chi - D \chi_c + \rho a S_{\chi_c}
\]

\[
\rho \frac{\partial}{\partial t} (a w_c) = -\frac{\partial}{\partial z} \left(\rho a \bar{w}^2 c\right) - D w_c + \rho a \frac{B_c}{1 + \gamma} - \frac{\partial}{\partial z} (a P_c)
\]
Parameterization of Cloud-Chemical Processes

Oxidation of S(IV) in cloud liquid water

\[
\begin{align*}
S(IV) + O_3 & \rightarrow S(VI) + O_2 \quad (\text{Maahs, 1983}) \\
S(IV) + H_2O_2 & \rightarrow S(VI) + H_2O \quad (\text{Martin, 1984})
\end{align*}
\]

\[
[S(IV)] = [SO_2] + [HSO_3^-] + [SO_3^=], \quad [S(VI)] = [SO_4^=]
\]

Equilibrium between gaseous and dissolved species

\[
\begin{align*}
H_2O & \leftrightarrow H^+ + OH^- \\
SO_2(g) & \leftrightarrow SO_2(aq) \\
O_3(g) & \leftrightarrow O_3(aq) \\
H_2O_2(g) & \leftrightarrow H_2O_2(aq) \\
CO_2(g) & \leftrightarrow CO_2(aq) \\
HNO_3(g) & \leftrightarrow HNO_3(aq)
\end{align*}
\]

\[
\begin{align*}
NH_3(g) & \leftrightarrow NH_3(aq) \\
SO_2(aq) & \leftrightarrow HSO_3^- + H^+ \\
HSO_3^- & \leftrightarrow H^+ + SO_3^= \\
CO_2(aq) & \leftrightarrow HCO_3^- + H^+ \\
NH_3(aq) + H^+ & \leftrightarrow NH_4^+ \\
HNO_3(aq) & \leftrightarrow H^+ + NO_3^-
\end{align*}
\]
Sulphur Cycle in AGCM4: Comparisons With Observations During PEM

Sept-Oct 1991

Feb-Mar 1994

Aug-Sept 1996

Aug-Sept 1996
Sulphur Cycle in AGCM4: Comparisons With Observations During PEM - Using Spectral Advection/Hybrid Variable

< 5000m

Model (ng/m³) vs Observations (ng/m³)

model/obs ratio = 0.80
correlation = 0.31

> 5000m

Model (ng/m³) vs Observations (ng/m³)

model/obs ratio = 1.50
correlation = 0.21
Sulphur Cycle in AGCM4: Comparisons With Observations During PEM - Using Semi-Lagrangian Transport

< 5000m

model/obs ratio = 1.20
correlation = 0.27

> 5000m

model/obs ratio = 3.97
correlation = 0.23
Sulphur Cycle in AGCM4: Results

Zonal mean
$SO_4 =$ concentration
(in ppb)