Fixing a problem in aerosol mass flux divergence computation with wet scavenging in cumulus convection scheme

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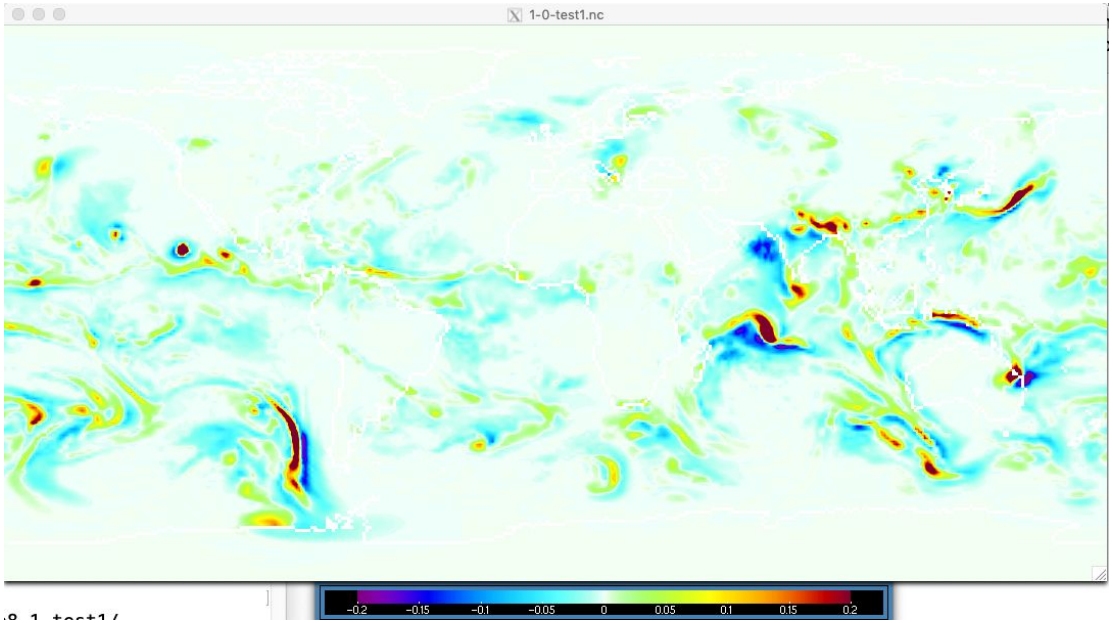
fscav=1.0 minus fscav=0.0 in P8B total AOD

fscav: convective wet scavenging factor

fscav=1.0: maximum convective wet scavenging,
fscav=0.0: no convective wet scavenging

For the differences of “fscav=1.0 minus fscav=0.0”, we would expect negative values in AOD differences over cumulus convection regions

fscav=1.0 minus fscav=0., P8B total AOD



There are many areas with positive AOD differences, indicating a problem in wet scavenging computation.

Mass flux transport of aerosol with wet scavenging in cumulus convection

$$\frac{\partial \phi_u}{\partial z} = -\varepsilon_u (\phi_u - \bar{\phi})$$

$$\phi_u = \left[1 - f_s \frac{c_0 \Delta z}{1 + c_0 \Delta z} \right] \phi_u$$

f_s: wet scavenging factor (0~1.0)
c_0: rain conversion rate

$$\frac{\partial \bar{\phi}}{\partial t} = \frac{\partial}{\partial z}\left[M_u \bar{\phi} \right] - \frac{\partial}{\partial z}\left[M_u \phi_u \right]$$

Problem in numerical representation of aerosol mass flux divergence computation in cumulus convection scheme

Aerosol parcel property (ecko) in the original code with wet scavenging (fcsav); xlamue: entrainment rate; c0t: rain conversion rate,

```
      do k=1, km
      do i=1,im
         dz = zi(i,k) - zi(i,k-1)
         tem  = 0.25 * (xlamue(i,k)+xlamue(i,k-1)) * dz
         factor = 1. + tem
         ecko(i,k) = ((1. - tem) * ecko(i,k-1) + tem *
     &                (ctro(i,k) + ctro(i,k-1))) / factor
         chem_c(i,k) = fscav * ecko(i,k)
         tem = chem_c(i,k) / (1. + c0t(i,k) * dz)
         ecko(i,k) = tem + ecko(i,k) - chem_c(i,k)
      enddo
      enddo
```

Vertical mass flux divergence of aerosol (dellae); eta: normalized mass flux,

```
      do k=1,km
      do i=1,im
         dz = zi(i,k) - zi(i,k-1)
         tem1 = -eta(i,k) * ecko(i,k)
         tem2 = -eta(i,k-1) * ecko(i,k-1)
         dellae(i,k) = (tem1-tem2) / (rho * dz)
      enddo
      enddo
```

Wet scavenging effect is taken into account in both upper and lower levels in vertical mass flux divergence computation of aerosol, while it should be in each layer.

Fixing the problem in numerical representation of aerosol mass flux divergence computation in cumulus convection scheme

Aerosol parcel property (ecko) in the original code with wet scavenging (fcsav); xlamue: entrainment rate; c0t: rain conversion rate,

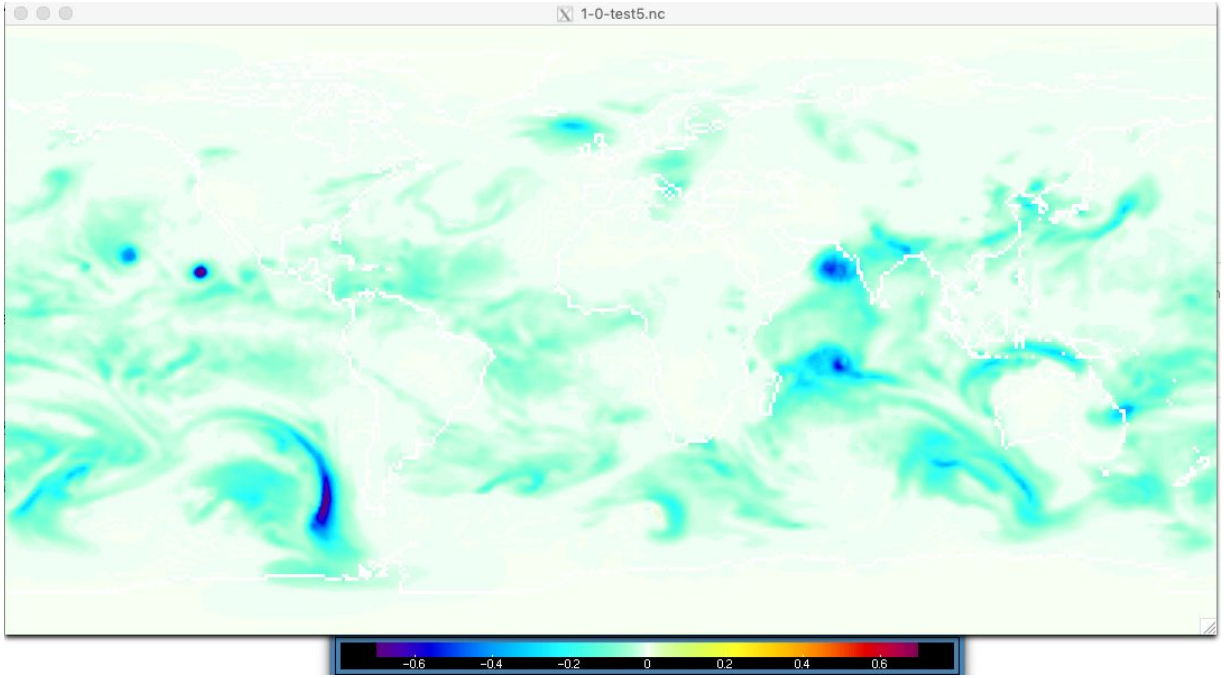
```
      do k=1, km
      do i=1,im
         dz = zi(i,k) - zi(i,k-1)
         tem  = 0.25 * (xlamue(i,k)+xlamue(i,k-1)) * dz
         factor = 1. + tem
         ecko(i,k) = ((1. - tem) * ecko(i,k-1) + tem *
     &                (ctro(i,k) + ctro(i,k-1))) / factor
         ercko(i,k) = ecko(i,k)
         chem_c(i,k) = fscav * ecko(i,k)
         tem = chem_c(i,k) / (1. + c0t(i,k) * dz)
         ecko(i,k) = tem + ecko(i,k) - chem_c(i,k)
      enddo
      enddo
```

Vertical mass flux divergence of aerosol (dellae); eta: normalized mass flux,

```
      do k=1,km
      do i=1,im
         dz = zi(i,k) - zi(i,k-1)
         tem1 = -eta(i,k) * ercko(i,k)
         tem2 = -eta(i,k-1) * ecko(i,k-1)
         dellae(i,k) = (tem1-tem2) / (rho * dz)
      enddo
      enddo
```

Wet scavenging effect is now taken into account in each layer in vertical mass flux divergence computation of aerosol, conserving aerosol mass during mass flux transport with wet scavenging.

fscav=1.0 minus fscav=0., P8B total AOD



Alternative mass flux transport of aerosol with wet scavenging in cumulus convection

$$\frac{1}{M_u}\frac{\partial M_u}{\partial z} = \varepsilon_u - \delta_u \qquad \frac{\partial (M_u \phi_u)}{\partial z} = \varepsilon_u \bar{\phi} - \delta_u \phi_u$$

$$\phi_u = \left[1 - f_s \frac{c_0 \Delta z}{1 + c_0 \Delta z}\right] \phi_u$$

f_s: wet scavenging factor (0~1.0)
c_0: rain conversion rate

$$\frac{\partial \bar{\phi}}{\partial t} = \frac{\partial}{\partial z}\left[M_u \bar{\phi}\right] - \frac{\partial}{\partial z}\left[M_u \phi_u\right]$$