Cloud-Resolving Simulations Using the WRF Model Driven by Large-Scale Forcings

Satoshi Endo, Yangang Liu, Wuyin Lin, and Gang Liu
The FASTER project plans to use the WRF model as a cloud resolving model (CRM) to provide dataset for the evaluation and development of parameterizations in climate models.

**Default function of WRF-LES (em_les)**
- Horizontally uniform initial condition
- Periodic boundary conditions
- Only constant sensible heat flux
- No radiation, no Coriolis, ....

**Not enough**

We extend the capability of WRF-LES for the CRM simulations and evaluate it against other models’ results.

**The modified WRF (WRF-FASTER)**
- Prescription of horizontally uniform time-varying large-scale forcings
- Prescription of surface sensible heat flux, latent heat flux, albedo and skin temperature
- And more.
Continental Shallow Cumulus (ARM SGP)

- Idealized simulation of cumulus topped convective boundary layer on 21 June 1997 at ARM SGP site (one of the GCSS inter-comparison cases; Brown et al. 2002)

- WRF-FASTER produced similar diurnal variation of clouds to KNMI-LES.

![WRF-FASTER and KNMI-LES graphs]

- Total cloud fraction
- Liquid water path
- Max. height of cloud top
- Min. height of cloud base
- Local time [hour]
- Total & Max CF
Maritime Stratocumulus (DYCOMS-II RF02)

- Idealized simulation of stratocumulus based on the 2nd research flight (RF02) of DYCOMS-II project.

- Another GCSS inter-comparison case (Ackerman et al., 2009)

- Configuration follows the specification except for vertical resolution.

<table>
<thead>
<tr>
<th>Period</th>
<th>6 hours with nighttime setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution (Domain)</td>
<td>50 m x 50 m x 7.5 m (average)</td>
</tr>
<tr>
<td></td>
<td>(6400 m x 6400 m x 1500 m)</td>
</tr>
<tr>
<td>Microphysics</td>
<td>Lin et al. scheme with cloud water sedimentation and Nc = 55 cm(^{-3})</td>
</tr>
<tr>
<td>Turbulence</td>
<td>TKE scheme</td>
</tr>
<tr>
<td>Radiation</td>
<td>SW: None  LW: Stevens et al. (2005)</td>
</tr>
<tr>
<td>Surface</td>
<td>Constant friction velocity (0.25 ms(^{-1})), SHF (16 Wm(^{-2})) and LHF (93 Wm(^{-2})).</td>
</tr>
<tr>
<td>Forcing</td>
<td>Surface forcing above. Subsidence (div = 3.75 x 10(^{-6}) s(^{-1})) and consequential heating, drying.</td>
</tr>
</tbody>
</table>
Time evolution

- Mean cloud top
- Total CF
- LWP
- Mean cloud base
- Max. w variance

WRF-FASTER

Ensemble Mean

Ensemble Range
Profile

Potential temperature

Total water

Cloud fraction

Averaged over all the domain and the final 4 hours

Liquid water PT flux

Total water flux

Liquid water
Summary

- Additional functions were implemented into WRF, including prescription of time-varying large-scale and surface forcings.

- The properties of simulated **continental shallow cumulus clouds** agreed well with that of KNMI-LES, and those of simulated **maritime stratocumulus clouds** dropped in the range of spreading among other models.

- Though not shown here (shown in POSTER), **frontal clouds** in March 2000 IOP at SGP were also simulated using continuous forcings. The results were comparable to those of other models.
The ARM SGP case: Vertical profile

Averaged over all the domain and time period of 12-13 LT

Potential temperature

Total water

Cloud & core fraction ($q_c > 0$ and $\theta_v' > 0$)

Heat flux (liquid water PT flux)

Total & liquid water flux

Cloud & core mass flux

Core mass flux (Fig. 8 of Brown et al.)