Chapter 2
The Grid-Point Atmospheric Model of IAP LASG–Version 2: GAMIL2

Lijuan Li, Bin Wang, Li Dong, Li Liu, Ye Pu, Si Shen, Wenyu Huang, Wenqi Sun, Yong Wang and Xiangjun Shi

Abstract Version 2 of the Grid-point Atmospheric Model of IAP LASG (GAMIL2) has been developed by upgrading the deep convection parameterization, the cumulus cloud fraction and the two moments cloud microphysical scheme, and by changing some of the large uncertain parameters. In the present study, cloud simulations by GAMIL2 were evaluated using the satellite simulator and the CAPT method (i.e., the Climate Change Prediction Program (CCPP)—Atmospheric Radiation Measurement Program (ARM) Parameterization Testbed). Here, the shortwave cloud radiative forcing (SWCF) response of atmosphere circulation to the Niño 3 sea surface temperature anomaly and the indirect aerosol effect are discussed.

Keywords GAMIL2 · Satellite simulator · Cloud · SWCF

The Grid-point Atmospheric Model of IAP LASG (GAMIL) is based on the finite difference dynamical core, which was developed in the National Key Laboratory for Numerical Modeling of Atmospheric Sciences and Geophysical Fluid Dynamics (LASG), Institute of Atmospheric Physics (IAP), Chinese Academy of Sciences (CAS). Its horizontal grids include a uniform zonal grid (with grid interval of 2.8°) and a hybrid meridional grid with a Gaussian grid in the zone between 65.58°S and 65.58°N (with grid length of about 2.8°) and a weighted equal-area grid in the high latitudes and polar regions (with grid size typically

L. Li (✉) · B. Wang · L. Dong · Y. Pu · S. Shen · W. Sun · Y. Wang · X. Shi
State Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics (LASG), Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing 100029, China
e-mail: ljli@mail.iap.ac.cn

B. Wang · L. Liu · W. Huang
Ministry of Education Key Laboratory for Earth System Modeling, Center of Earth System Science (CESS), Tsinghua University, Beijing 100084, China

X. Shi
Climate Center, Hebei Meteorological Administration, Shijiazhuang 050021, China

T. Zhou et al. (eds.), *Flexible Global Ocean–Atmosphere–Land System Model*,
Springer Earth System Sciences, DOI: 10.1007/978-3-642-41801-3_2,

greater than 2.8°). The model includes 26-σ vertical levels (pressure normalized by surface pressure) with the model top at 2.194 hPa. The dynamical core is computationally very stable without any filtering or smoothing in the polar region, and some important integral properties are conserved exactly, such as the antisymmetries of the horizontal and vertical advection operators, the mass conservation, and the effective total energy conservation under the standard stratification approximation (Wang et al. 2004a).

With regards to the physical schemes adopted, the main differences between GAMIL1 (Wang et al. 2004a; Li and Wang 2010) and GAMIL2 (Li et al. 2012b, 2013d) are related to the upgraded cloud-related processes, including deep convective parameterizations (Zhang and McFarlane 1995; Zhang and Mu 2005), convective cloud fraction (Rasch and Kristjánsson 1998; Xu and Krueger 1991), and microphysical schemes (Rasch and Kristjánsson 1998; Morrison and Gettelman 2008; Shi et al. 2010). Moreover, for the energy balance at top of atmosphere (TOA), some parameters relating to convection (including shallow and deep convection), cloud macro/microphysical properties, and boundary layer schemes have been changed in GAMIL2; more detailed information can be found in Li et al. (2013d).

GAMIL2 reproduced the total cloud fraction reasonably well, with maximum (0.97), minimum (0.25), and global mean (0.61) values similar to the corresponding values (0.99, 0.20, and 0.69, respectively) derived using the Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) (Fig. 2.1). The maximum cloud fractions were found to occur in the Intertropical Convergence Zone (ITCZ) and along mid-latitude storm tracks, and the minima that occur over the subtropical zone were also well simulated by GAMIL2. Further information regarding other cloud types can be found in Dong et al. (2012).

In addition to the satellite simulator, the CAPT method (i.e., the Climate Change Prediction Program (CCPP)–Atmospheric Radiation Measurement Program (ARM) Parameterization Testbed) has also been used to assess climate model parameterizations in recent years (Phillips et al. 2004). At Darwin station, during the Tropical Warm Pool–International Cloud Experiment (TWP–ICE),

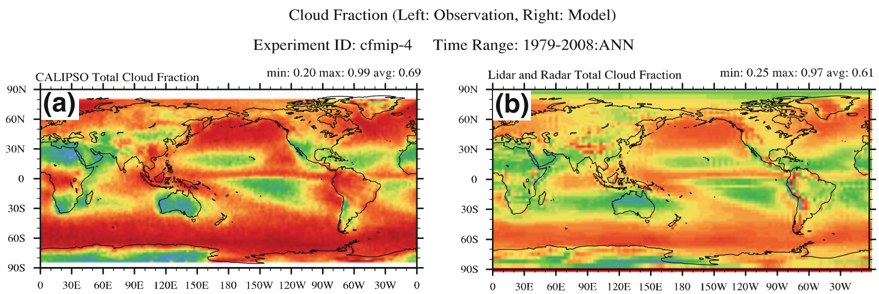

Fig. 2.1 Total cloud fractions from **a** CALIPSO observations and **b** GAMIL2 using the CALIPSO satellite simulator

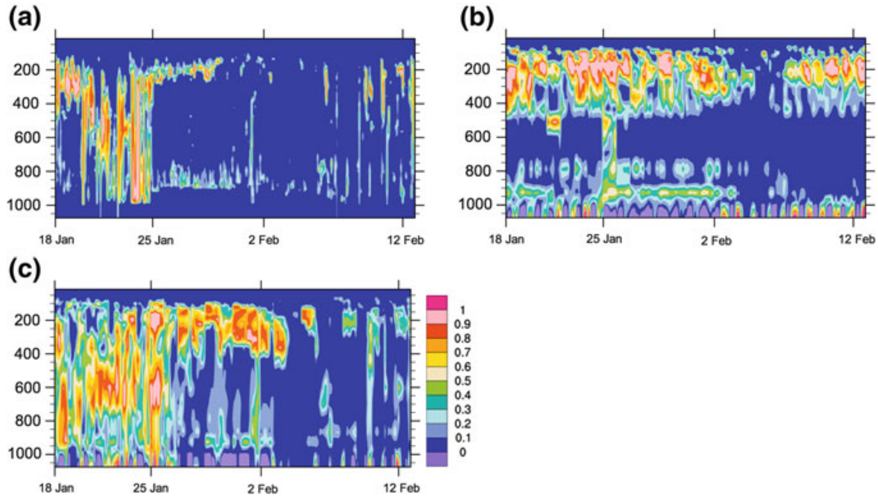

Fig. 2.2 Temporal evolution of cloud fraction at Darwin station during TWP–ICE period: **a** Observed and simulated by **b** GAMIL1 and **c** GAMIL2 (from Li et al. 2012c)

GAMIL1 produced high clouds at all times and failed to describe the different characteristics of the three distinct monsoon conditions (Fig. 2.2b). By comparison, GAMIL2 exhibited reasonable agreement with the observations, although some apparent biases remained (Fig. 2.2c); these improvements can be attributed primarily to the improved convective parameterizations. Cloud heights in GAMIL2 were higher than those observed, and more convective clouds appeared on 18–19 and 25–26 January 2006 when no convective system developed or persisted in the observations (Li et al. 2012b).

Consistent with the improvement of cloud fraction simulations, GAMIL2 also has greatly reduced the biases of the shortwave cloud radiative forcing (SWCF) simulation, particularly in the central tropical Pacific and northwestern Indian Ocean (Fig. 2.3). The global mean values derived using GAMIL2 were found to be closer to the Clouds and the Earth's Radiant Energy System (CERES) Energy Balanced and Filled (EBAF) product than those derived using GAMIL1; the GAMIL2 RMSEs were also found to be smaller than those for GAMIL1.

GAMIL2 also offers a significant improvement in terms of the strength of the atmospheric response to the tropical Pacific Ocean, which is measured using the regression coefficient between the Southern Oscillation Index (SOI) and Niño 3 sea surface temperature anomaly (SSTA) (Fig. 2.4), and this advance cloud be connected to the coordination of moist processes, e.g., convection and cloud micro/macro-physical processes. The indirect effects of the prescribed aerosols on the SWCF, liquid water path (LWP), and column droplet number concentration (CDNC) are shown in Table 2.1, which illustrates the differences between the present-day (PD) and preindustrial (PI) values of these parameters. The global mean SWCF difference induced by aerosols was found to be $-0.94\ \mathrm{Wm}^{-2}$, which

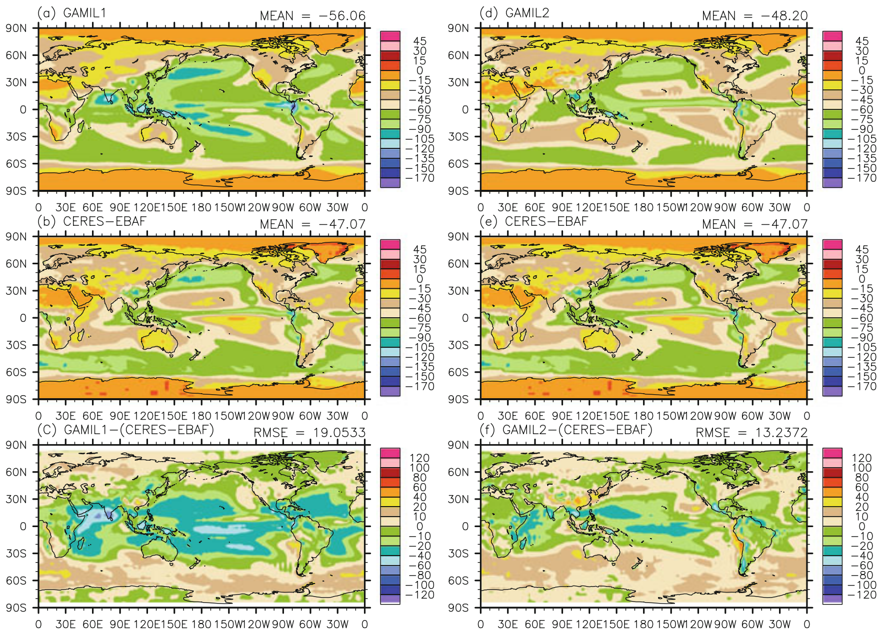

Fig. 2.3 Annual mean shortwave cloud radiative forcing for both versions of GAMIL and the CERES EBAF product (units: Wm^{-2}, from Li et al. 2013d)

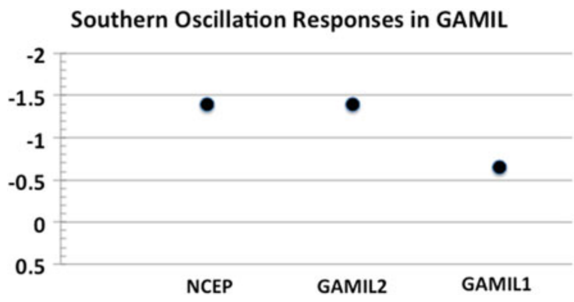

Fig. 2.4 Regression coefficients between the Southern Oscillation Index (SOI) and Niño 3 SSTA. Here, SOI is defined the difference between Tahiti and Darwin pressure (units: hPa $°C^{-1}$, from Li et al. 2013d)

Table 2.1 Global, Northern Hemisphere (NH), and Southern Hemisphere (SH) annual mean changes in shortwave cloud forcing (SWCF, Wm^{-2}), liquid water path (LWP, gm^{-2}), and column droplet number concentration (CDNC, × 109 m^{-2}) between PD and PI (PD–PI)

	SWCF (Wm^{-2})	LWP (gm^{-2})	CDNC (109 m^{-2})
Global	−0.94	4.76	3.51
NH	−1.31	7.46	5.83
SH	−0.58	2.05	1.18

falls within the range (-2 to 0 $\mathrm{Wm^{-2}}$) estimated by the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC). The cooling effect in the Northern Hemisphere (NH) was found $-1.31\ \mathrm{Wm^{-2}}$; this is greater than the $-0.58\ \mathrm{Wm^{-2}}$ found for the Southern Hemisphere (SH), which is in agreement with the distribution of aerosols such as sulfate.

Acknowledgments This work was jointly supported by the Knowledge Innovation Program of the Chinese Academy of Sciences (Grant No. KZCX2-YW-Q11-04), the National High Technology Research and Development Program of China (863 Program, Grant No. 2010AA012304), the National Basic Research Program of China (973 Program, Grant No. 2010CB951904), the Chinese Academy of Sciences Strategic Priority Research Program (Grant No. XDA05110304), and the National Natural Science Foundation of China (Grant Nos. 41023002 and 41005053).

Springer
http://www.springer.com/978-3-642-41800-6

Flexible Global Ocean-Atmosphere-Land System Model
A Modeling Tool for the Climate Change Research Community
Zhou, T.; Yu, Y.; Liu, Y.; Wang, B. (Eds.)
2014, XVI, 483 p. 176 illus., 152 illus. in color., Hardcover
ISBN: 978-3-642-41800-6