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Atmospheric Chemistry and Physics Discussions

Interactive comment on "A compressed super-parameterization: test of NAM-SCA under single-column GCM configurations" *by* J.-I. Yano et al.

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Reply to Referee #1:

We appreciate the way that present referee summarizes our article. We are especially glad to know that the present referee much appreciates our extensive documentation on the performance of NAM–SCA. As the referee correctly points out, unimportance of the role of mesoscale organization in predicting Q_1 and Q_2 is one of major conclusions from the present study.

We also graceful to the present referee for pointing out some shortcomings of the present manuscript.

More specifically,

- We will put sufficient descriptions and references to the SCM models in revision, especially on their physics. Difference between the two SCMs will carefully be discussed.

- The intercomparisions of precipitation time series, albeit so basic, reveal the shortcomings of various models that we use in the present study. Unfortunately, none of the models that we have investigated nicely fits to the observations. They are, rather, more than often off by an order of magnitudes. In the present paper, we decide to show those uncomfortable aspects objectively.

- Note that plots versus dx and domain size are the most straightforward manner to demonstrate unimportance of the mesoscale organization in Q_1 and Q_2 predictions, albeit they may look bit too abstract for general readers. Nevertheless, these graphics are simple enough to master in relatively short time.

Specific Comments:

1. Introduction:

- Detailed description for ECHAM and ACCESS physics are given in the Appendix A and B, below, respectively. Those include: convection scheme, cloud scheme, microphysics, boundary layer, and radiation. The Appendix C, separatetely, summarizes the differences between these two models.

Note that the time step and the vertical resolution are discussed in Sects. 2.1 and 2.4, respectively. The Appendix A2 lists more specific information on the vertical coordinate. As described in the text, the vertical resolution of the model is kept the same as or comparable to the host models. Furthermore, vertical resolutions of ECHAM and ACCESS are also very similar. Differences in physics are clearly more substantial. Also note that neither SCM makes assumptions on the grid–box size.

2. Formulation of the problem

2.2. Cloud fraction & radiation

As discussed in Appendices A–C, ECHAM does not distinguish between liquid and ice clouds, whereas ACESS (PC2) requires fractions for liquid and ice clouds, separately. For the latter, a special provision is applied as already discussed in the text.

4. Results

4. 1. Results with default GCM–SCMs

After carefully re–examining our analysis results, we found that all the default ECHAM analyses are based on runs with 1–hourly and 3–hourly means for GATE and TWP–ICE cases, respectively. For this reason, instantaneous errors for the default ECHAM cases are computed in new along with the moving–averaged errors as requested by the present referee. For a moving average length, we decide to take 6–hours and 3–hours, respectively, for the GATE and the TWP–ICE cases in order to match with the data intervals for both cases. Those results are summarized in the Table at the end of the present reply. There, also the errors with 1–hourly and 3–hourly averages are shown for the ECHAM GATE case.

In revision, all the statistics will be taken against the (corrected) instantaneous precipitation errors for the ECHAM GATE case. As a result, Figs. 20 and 25 are revised as shown in Fig. 1:

Furthermore, in revision, we will show the instantaneous precipitation time series also for the ECHAM cases as shown in Fig. 2:

As further requested by the present referee, we have computed the NAM–SCA precipitation errors also under 6–hourly and 3–hourly moving averages, respectively, for the GATE and the TWP–ICE cases. These results are shown below in the order of the stand–alone case, as well as coupling with ECHAM and ACCEES. All the errors are shown under normalization as described in the manuscript, but with 6–hourly and 3–hourly averaged default cases, respectively, for GATE and TWP–ICE in Figs. 3–5.

Recall that the ACCESS errors are used for normalizing the stand–alone cases.

4.3.1.

The issues of ice microphysics for the TWP–ICE case will be remarked in revision by referring to Varble et al. (2011).

4.5.

It would be important to emphasize that implementation of NAM–SCA into any SCM is self–consistent by design, as carefully explained in Sect. 2. However, as this section shows, ECHAM prediction performance does not necessarily improve by implementing NAM–SCA. As already suggested in the current text, it happens because ECHAM has already tuned to provide the best result with a combination of the default physics. Replacing few components (convection and clouds) by presumably better ones does not necessarily lead to better results due to the issue of combinations with the other physics. This is not a matter of consistency, but tuning.

Technical corrections:

1. Page 28253, last sentence in 1st paragraph: this grammatical error will be corrected in revision

2. Page 28271, Line 19: a space in GATE will be removed in revision

3. Fig. 3: small unexplained numbers (50 8 1) are removed in the revised graphics. See Fig. 6 below.

In process of removing those numbers, we have also find a minor bug in this graphic code. The best fit slop for the scatter as well as general scatter tendency slightly change as a result. Note especially a noticeable deviation of scatter from the fit for $Q_2 \gg 0$.

4. The text and numbers on the axes of all the Q1 and Q2 figures have been enlarged as shown in Figs. 7–13.

5. A small text stuck at the top of (a) and (c) are removed from Figs. 18 and 21. See the revised graphics below:

Appendix A: ECHAM–SCM Physics

The ECHAM physics are reviewed by Stevens, et al (2013).

A.1 Convection

A bulk mass–flux scheme originally developed by Tiedtke (1989) is used for moist convection parameterization. The current scheme includes shallow and midlevel convection in addition to deep convection, but with only one convection type allowed at any given time. A preference is given to deep convection. A component for deep convection is revised by Nordeng (1994), whereas shallow and midlevel convection uses the original Tiedtke formulation.

Closure is based on convective available potential energy (CAPE) for deep convection, whereas moisture closure is adopted for shallow convection. Details are discussed in Möbis and Stevens (2013).

A.2 Clouds

The cloud fraction is evaluated by a simple diagnostic formulation depending on the grid–point relative humidity as proposed by Sundqvist et al (1989, see their Eq. 3.13). A critical relative humidity, a free parameter of the formulation, is adjusted based on a cloud–resolving model study by Xu and Kruger (1991).

A.3 Cloud Microphysics

Large–scale cloud microphysics are described by a single-moment bulk scheme (Lohmann and Roeckner 1996). The scheme considers the three types of water: vapour, liquid, ice. Warm microphysics formulation is basically taken from Beheng (1994) double–moment formulation, but it is simplified by assuming prescribed cloud and rain number concentrations by environment. Ice physics are developed strictly in

bulk manner by assuming an exponential size distribution (Gunn and Marshall 1958). Large–scale precipitation is treated diagnostically given the conversion terms from the prognostically–described water phases. Detrainment of hydrometeors from parameterized convection is also taken into account.

A.4 Other physics

The boundary–layer scheme is based on a 1.5–order closure in moment expansion with the turbulent kinetic energy (TKE) computed prognostically in order to define a eddy diffusion coefficient (Brinkop and Roeckner 1995). Dependence of the eddy diffusion on TKE mimics the cloud-top entrainment.

Radiation calculation is based a two–stream formulation by Iacono et al (2008). Maximum–random cloud overlap (cf., Geleyn and Hollingworth 1979) is assumed for considering the radiative–cloud interactions.

Appendix B: ACCESS–SCM Physics

The ACCESS SCM used in the present study is based on the Australian Parallel Suite 1 (APS1) ACCESS-G model, which is based on UKMO UM7.5. Details on APS1 are described in the NMOC Operations Bulletin Number 93, relating to APS1 upgrade of the ACCESS-G Numerical Weather Prediction system, which was released in November 2012 and is available at

http://www.bom.gov.au/australia/charts/bulletins/nmoc_bulletin.shtml.

B.1 Convection

A modified version of bulk mass–flux scheme originally developed by Gregory and Rowntree (1990) is adopted for moist convection parametrization. For deep convection, the cloud-base mass-flux is calculated based on the reduction of Convectively Available Potential Energy (CAPE) to zero over a given timescale. The CAPE closure has been modified in various ways to enhance model stability, with the vertical-velocity-based CAPE closure used. Under this framework, if the maximum large-scale vertical velocity, evaluated before convection, is larger than the threshold vertical velocity, the CAPE timescale is reduced in order to remove the convective instability more rapidly.

B.2 Clouds

The cloud fraction is computed prognostically with the prognostic cloud and condensate (PC2) scheme (Wilson et al., 2008). Under this scheme, fractions for liquid clouds and ice clouds are computed separately, but no mixed–phase cloud is considered. These two values are passed on to radiative transfer computations. In NAM–SCA implementation of ACCESS, these two cloud fraction values are replaced by those diagnosed from NAM–SCA as described in the main text.

PC2 provides a comprehensive framework for cloud descriptions by fully coupling it with cloud microphysics as well as by taking into account of the other processes such as detrained cloud water from convection, radiation, and boundary layer processes.

B.3 Cloud Microphysics

Large–scale cloud microphysics (Wilson and Ballard 1999) are described by a single-moment bulk scheme, overall based on Rutledge and Hobbs (1983). The scheme considers the three types of water: vapour, liquid, ice. A single ice water prognostic variable is further split by a diagnostic relationship into ice crystals and aggregates, which are treated separately in the microphysical conversion terms before being recombined after the calculations. The microphysical processes calculated in the scheme are: sedimentation of ice and rain, heterogeneous and homogeneous nucleation of ice particles, deposition and sublimation of ice, aggregation, riming and melting of ice, collection of cloud droplets by raindrops, autoconversion and accretion production of raindrops, and evaporation of rain (condensation and evaporation of cloud water is performed by the cloud scheme).

B.4 Other physics

The boundary–layer scheme, as described by Lock et al. (2000) and updated by Brown

et al. (2008), is based on an eddy–diffusion based approach with a vertical profile of the eddy–diffusion coefficient prescribed based on an environmental state (stable or unstable, etc). This procedure mimics “non–local” transport. The scheme also includes an explicit entrainment parameterization at the boundary–layer top.

Radiation calculation is based on two–stream approximation described by Edwards and Slingo (1996). Maximum–random cloud overlap (cf., Geleyn and Hollingworth 1979) is assumed for considering the radiative–cloud interactions.

Appendix C: Comparison of the two default SCM physics

C.1. Convection

Both models use a bulk mass–flux scheme with a CAPE closure as a default. However, they are different in details including the treatments of closure and entrainment–detrainment rates.

C.2. Clouds

For cloud fraction evaluation, ECHAM adopts a simple diagnostic formula (Sundqvist et al 1989), whereas ACCESS adopts an extremely elaborated PC2 scheme which contains extensive coupling with various physical processes (Wilson et al., 2008). The latter also compute the liquid and the ice cloud fractions separately. However, a careful examination of the latter formulation casts a doubt whether such an elaboration is an advantage.

C.3. Cloud microphysics

Though different in details of flavors, both models adopts the cloud microphysics descriptions with a comparable level of complexity.

C.4 Other physics

Both boundary–layer schemes are based on the idea of eddy diffusion. However, they take substantially different strategies in detail. ECHAM (Brinkop and Roeckner 1995) takes a 1.5–order closure, but strictly remains with local descriptions. On the other hand, ACCESS technically stays with a first–order closure, but overcomes its limitation by introducing a “non–local” dependence on the eddy–diffusion coefficient.

Both models assume two–stream approximation for the radiative–transfer calculations with a same level of complexity in details. Both models assume the maximum–random cloud overlap (cf., Geleyn and Hollingworth 1979).

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Table: summary of precipitation errors:

SCM case time–average : RMS error (mm/h)

ACCESS GATE instant : 2.274

ACCESS GATE 6-hourly : 0.4992

ACCESS TWP instant : 1.303

ACCESS TWP 3-hourly : 1.240

ECHAM GATE instant : 1.077

ECHAM GATE 1-hourly : 0.6708

ECHAM GATE 3-hourly : 0.5023

ECHAM GATE 6-hourly : 0.3752

ECHAM TWP instant : 0.8682

ECHAM TWP 3-hourly : 0.4899

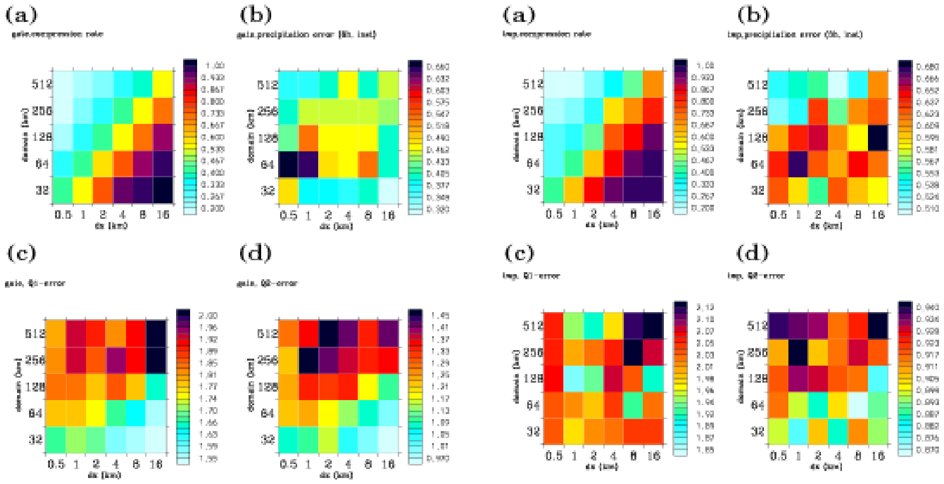

Fig. 1. Revised Figs. 20 (left) and 25 (right)

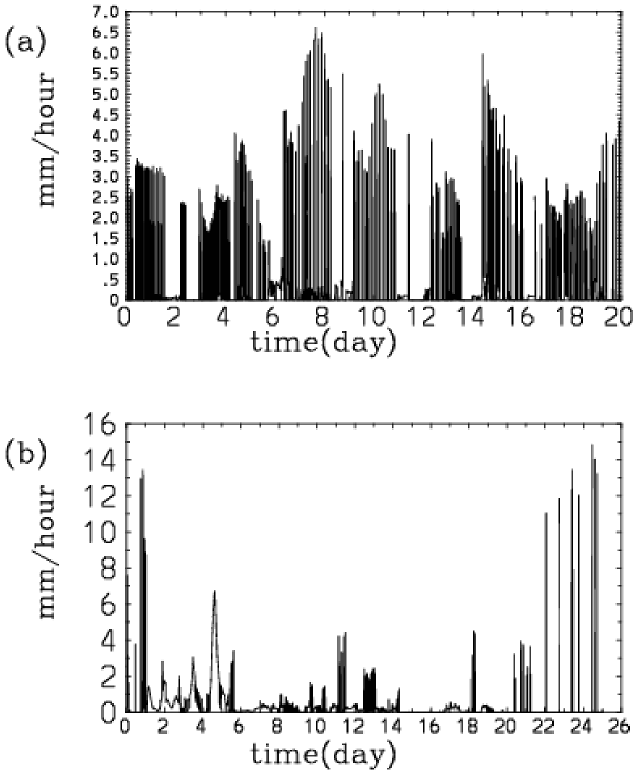

Fig. 2. Revised Fig. 6

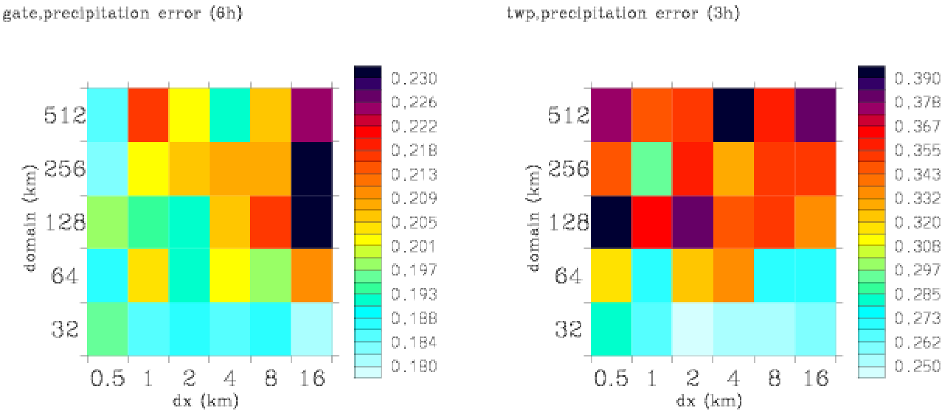

Fig. 3. Stand–alone cases with moving–averaged precipitation errors.

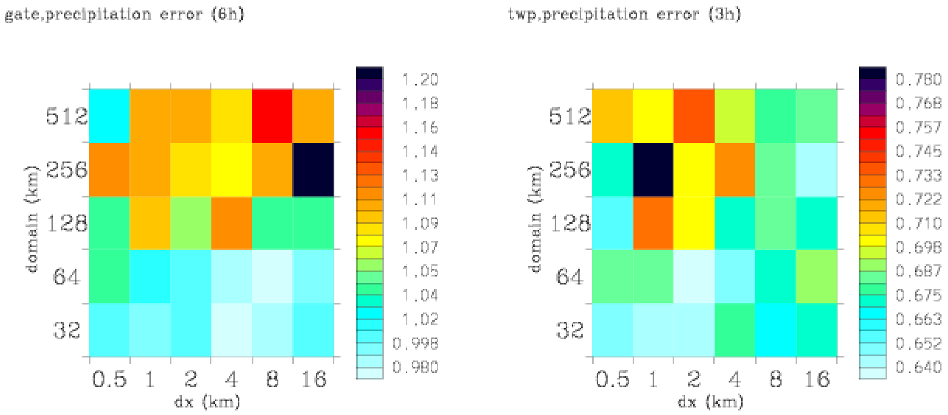

Fig. 4. ECHAM cases with moving–averaged precipitation errors.

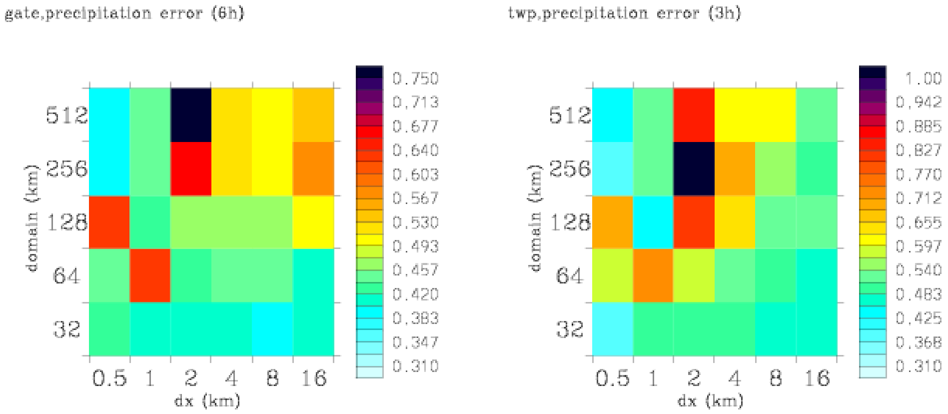

Fig. 5. ACCESS cases with moving–averaged precipitation errors.

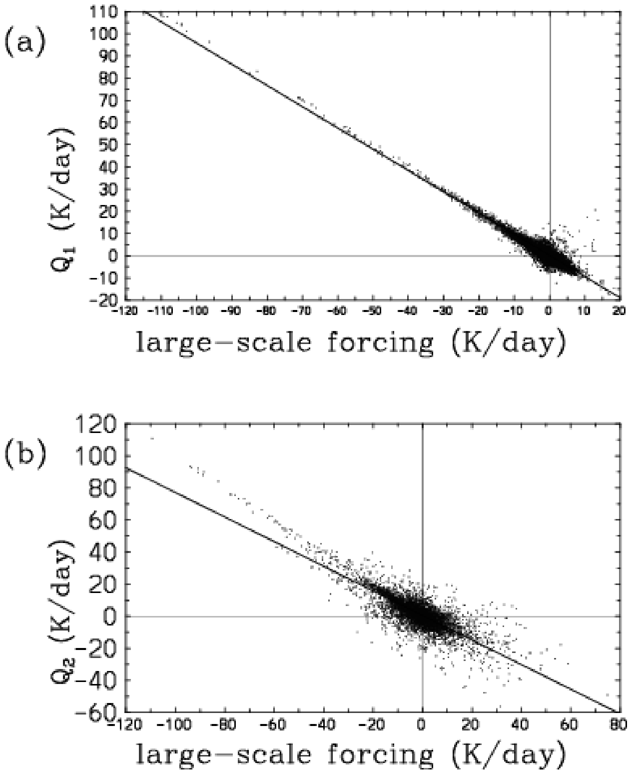

Fig. 6. Revised Fig. 3

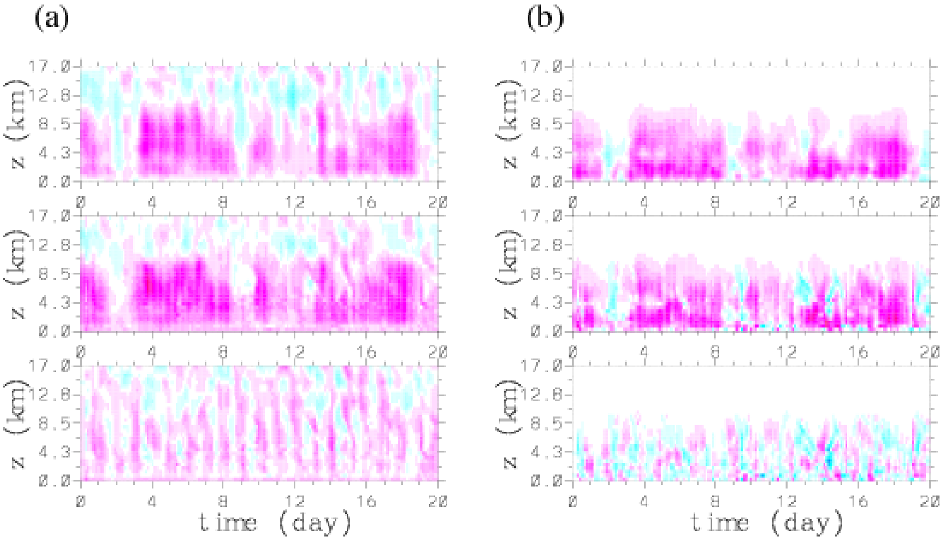

Fig. 7. Revised Fig. 7

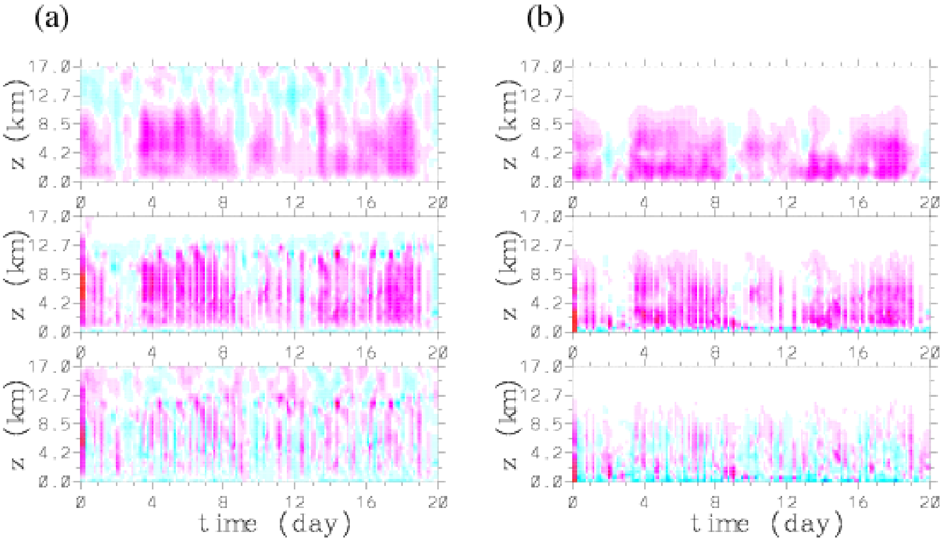

Fig. 8. Revised Fig. 8

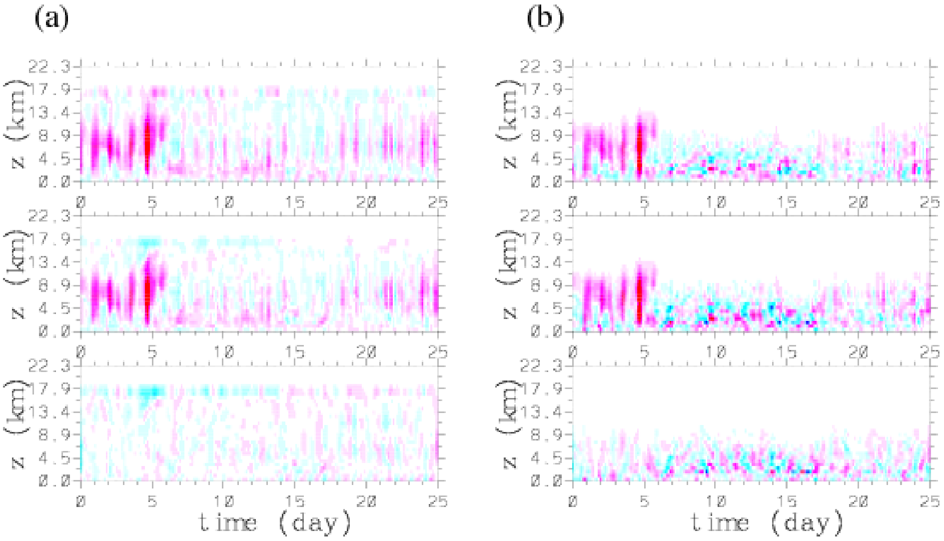

Fig. 9. Revised Fig. 9

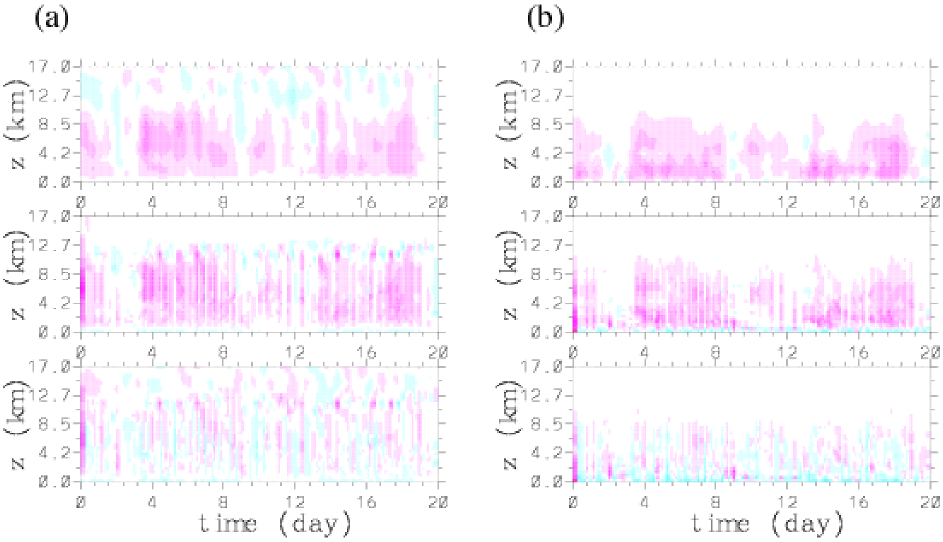

Fig. 10. Revised Fig. 10

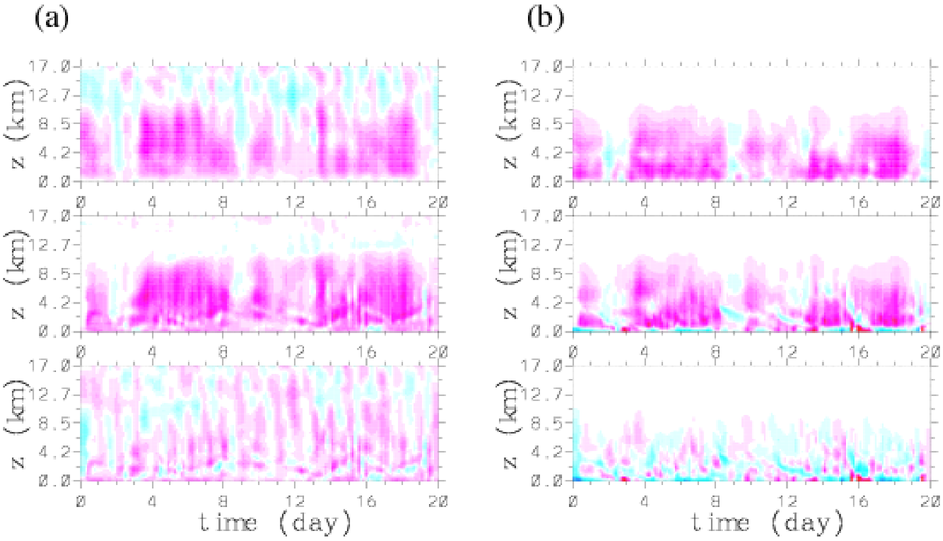

Fig. 11. Revised Fig. 13

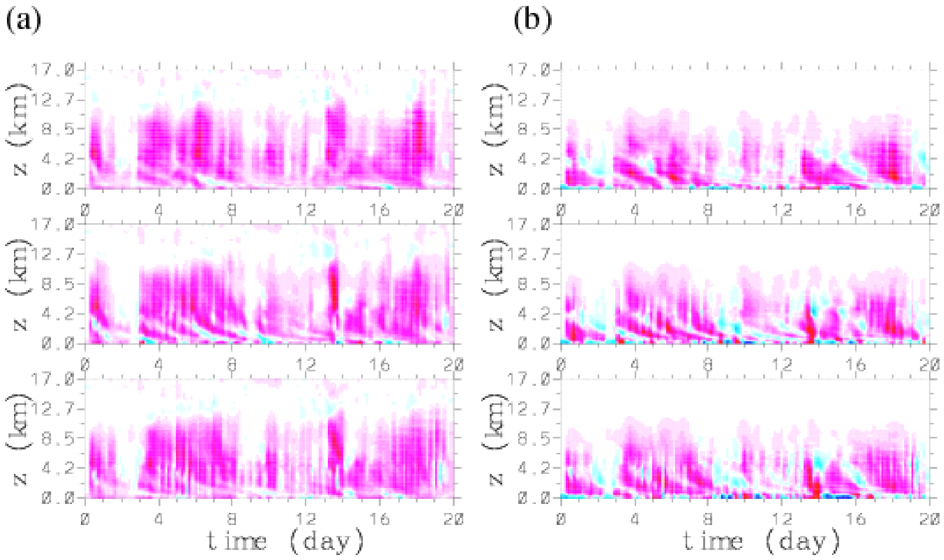

Fig. 12. Revised Fig. 14

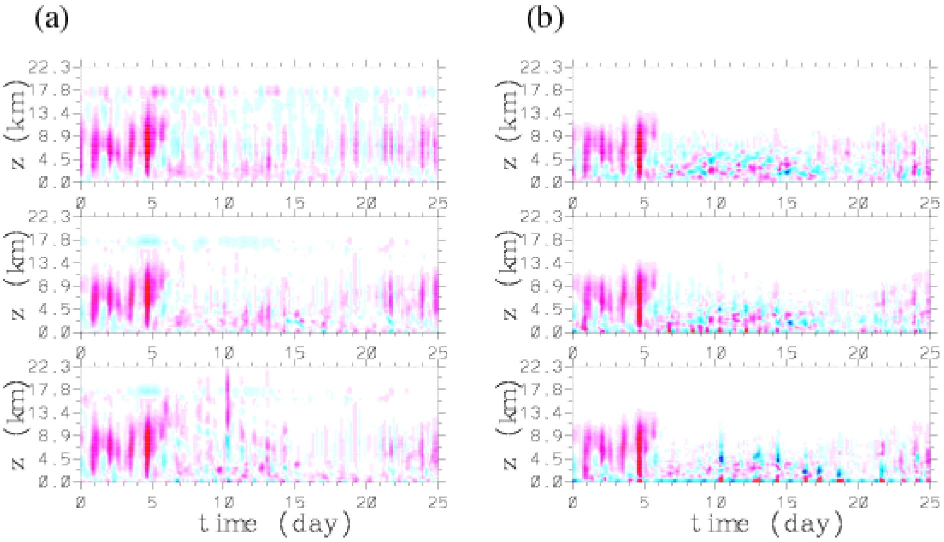

Fig. 13. Revised Fig. 19

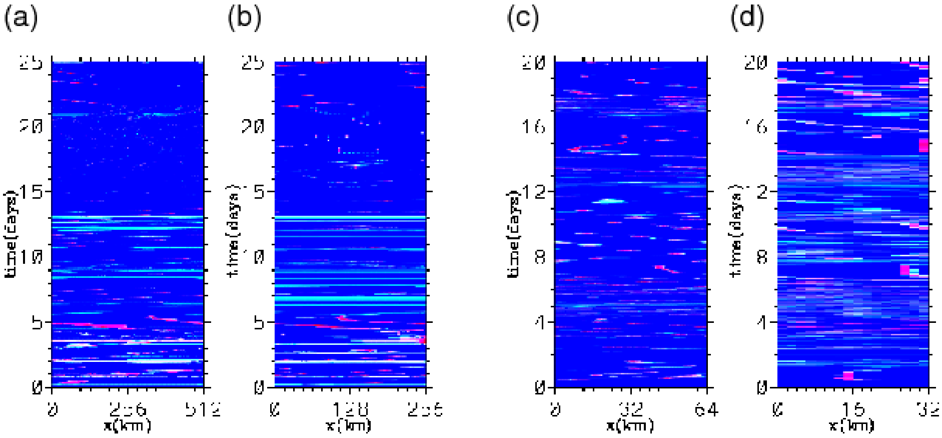

Fig. 14. Revised Fig. 18

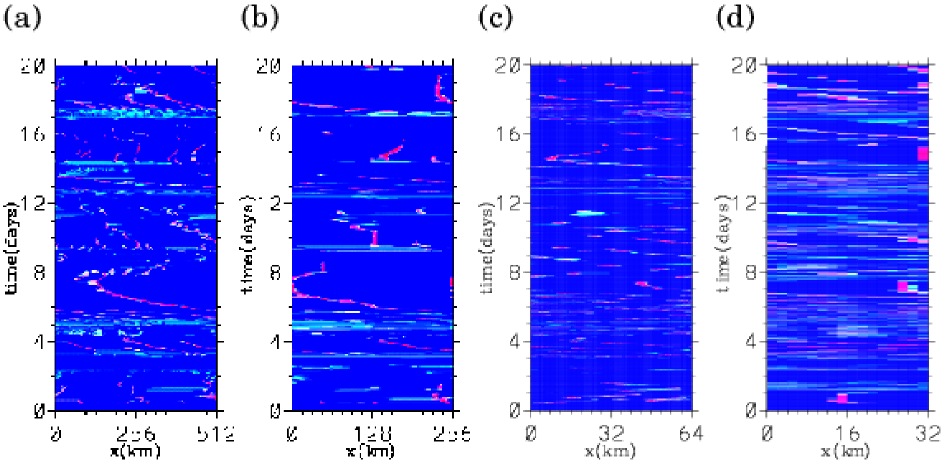

Fig. 15. Revised Fig. 21